IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES
WITH SPECIAL REFERENCE TO THE
BRITISH EMPIRE

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PREPARED UNDER THE DIRECTION OF THE
MINERAL RESOURCES COMMITTEE OF THE
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ANTIMONY ORES

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WITH A MAP

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GENERAL PREFACE

THE Mineral Resources Committee of the Imperial Institute has arranged for the issue of this series of Monographs on Mineral Resources in amplification and extension of those which have appeared in the *Bulletin of the Imperial Institute* during the past fifteen years.

The Monographs are prepared either by members of the Scientific and Technical Staff of the Imperial Institute, or by external contributors, to whom has been available the statistical and other special information relating to mineral resources collected and arranged at the Imperial Institute.

The object of these Monographs is to give a general account of the occurrences and commercial utilization of the more important minerals, particularly in the British Empire. No attempt has been made to give details of mining or metallurgical processes.

HARCOURT,
Chairman Mineral Resources Committee.

IMPERIAL INSTITUTE,
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ANTIMONY ORES

CHAPTER I

ANTIMONY ORES: THEIR OCCURRENCE, CHARACTERS AND USES

INTRODUCTION

ALTHOUGH the exact date when the metal antimony was first artificially produced is not known, it is certain that it was used in the preparation of printers' metal in the sixteenth, if not in the preceding, century. Native antimony was first recognized as such in 1748. The sulphide mineral stibnite has been known from very early times. It was employed by the ancients for colouring the hair, eyebrows, etc., and to increase the apparent size of the eye—whence they called the ore *platyopthalmon* (eye-expander). It is the *stimmi* of Dioscorides (first century), the *stibium* of Pliny, the *antimonium* of Geber (latter part of the fifteenth century), the *lupus metallorum* of the alchemists, and the *Spiessglas* of the Germans. Stibnite has long been employed by the women of the east as a medicine and as an article of toilet for darkening the eyebrows (*compare* 2 Kings ix, 30, and Ezekiel, xxiii, 40), and is the *Kohl* of the Arabs and Hebrews. Basil Valentine alludes to it in his *Triumph-Wagen des Antimonii*, which is believed by some to have been written in the fifteenth century, but is regarded by others as a forgery which first appeared about 1600. Valentine proved stibnite to contain sulphur, and, at a later date, he described the preparation of the metal by using iron as the reducing agent. He was well acquainted with "star" antimony (*see* p. 22). At that time antimony was used for mirrors and bells, as well as in printers' type. Prior to 1500, antimony sulphide was used for parting gold and silver, as well as silver and iron. Paracelsus, in the

sixteenth century, is said to have been the first to use a solution of antimony in wine as an emetic. A crude method of liquating antimony was described by Agricola in 1556 [1]. We are told that the upper pots in which the ore was reduced were twice as large as the lower pots, and that the cakes produced weighed 6, 10 or 20 *libræ*, according to locality.

Balthasar Rössler in 1650, and later still, Lazarus Ercker described primitive precipitation or iron reduction methods. The roast-reduction method was first used in the eighteenth century. The reverberatory furnace came into vogue about 1830. Direct smelting in blast furnaces was first attempted about 1878, and in 1896 electrolytic antimony first appeared in the market [2] [3/pp. 1–5].

Antimony is one of the minor metals. The average pre-war world's consumption, excluding antimonial lead, may be estimated at about 21,500 long tons. This amount was easily supplied by a few antimony-producing countries, such as China (from 1900 only), Borneo, Asia Minor, France and Hungary. At certain periods, however, there has been a great demand for the metal, owing to the sudden growth of old industries and to the establishment of new ones. As examples of such the periods 1880–81, 1890–91, 1906–7 and 1915–16 may be quoted. In 1906–7, not only had there been a considerable increase in the use of the metal in the industries, but European Governments were large buyers of antimony for ammunition purposes, and during the first two years at least of the Great War, antimony was in great demand for shrapnel bullets, and the production reached its highest figure of about 78,000 tons in 1916. In 1917–19 there was a considerable drop both in production and price. By 1920–21 the world's production was very little less than the pre-war production, but in 1922–23 there was a still further drop to about 13,750 tons per annum.

Besides the older uses, already mentioned, antimony is an ingredient of numerous anti-friction or bearing metals, of Britannia metal and other alloys used for domestic purposes. It is also made into a pigment or paint, and has a number of minor uses.

" The use of the metal in alloys is increasing, and the oxide

is finding a field in the manufacture of sulphurets and enamels. The low selling price ensures for it, against all competition, a place as one of the useful metals. The amount consumed will continue to increase so long as man requires more houses, machinery, automobiles, printed matter and chemicals" [4].

Antimony Minerals and their Associations

The principal antimony ores and minerals are included in the following table:

Class of Mineral.	Name.	Formula.	Antimony.	S.G.	Whether primary or secondary.
			%		
Sulphide	Stibnite	Sb_2S_3	71·4	4·52–4·62	P
Oxide.	Valentinite (rhombic)	Sb_2O_3	83·3	5–5·66	S
Oxide.	Senarmontite (cubic)	Sb_2O_3	83·3	5·22–5·30	S
Oxide.	Cervantite	Sb_2O_4	78·9	4·084	S
Hydroxide	Stibiconite	$Sb_2O_4.H_2O$ (?)	74·5	5·1–5·28	S
Oxysulphide	Kermesite	$2Sb_2S_3.Sb_2O_3$	75	4·5–4·6	S
Native	Native antimony	Sb	100	6·65–6·72	S

Stibnite.—Rhombic. Commonly in confused aggregates of acicular crystals, also in radiating groups; massive, coarse or fine, columnar. H = 2. Lustre metallic, highly splendent. Colour and streak lead-grey. May be known by its fusing easily, and by colouring a flame greenish-blue. In an open tube the oxide (Sb_2O_3) is condensed as a white sublimate. The mineral is also known as *antimonite, grey antimony,* or *antimony glance.*

Valentinite or *Antimony Bloom.*—Rhombic. Commonly in fan-shaped or stellar groups of crystals; also massive; structure lamellar, columnar, granular. H = 2·5–3. Lustre adamantive; shining. Colour snow-white. Streak white. Translucent to sub-transparent.

Senarmontite.—Cubic; in octahedrons. Also granular massive; in crusts. H = 2–2·5. Lustre resinous, inclining to subadamantine. Transparent to translucent. Colourless to greyish. Streak white.

Cervantite or Antimony Ochre.—Rhombic. In acicular crystallization. Also massive; as a crust or a powder.

H = 4·5. Lustre greasy or pearly. Colour, brownish-yellow, sulphur-yellow or nearly white. Streak, yellowish-white to white. B.B. infusible; easily reduced on charcoal.

Stibiconite or Stiblite.—Massive, compact. Also as a powder and in crusts. H = 4–5·5. Lustre pearly to earthy. Colour pale yellow to yellowish-white, reddish-white. In the closed tube gives off water, but does not fuse; on charcoal decrepitates, fuses with difficulty to a grey slag and gives a white coating.

Kermesite, Antimony Blende or Red Antimony.—Monoclinic; usually in tufts of capillary crystals. H = 1–1·5. Lustre adamantine. Colour cherry-red. It results from the partial oxidation of stibnite, changing by further oxidation to valentinite or cervantite.

Native Antimony.—Rhombohedral. Generally massive, also radiated; sometimes botryoidal or reniform. Fracture uneven, very brittle. H = 3–3·5. Lustre metallic. Colour and streak tin-white. B.B. fuses on charcoal, giving a white coating.

Besides the above, antimony occurs as antimonides of silver and other metals and in a number of complex sulphides and oxides, as will be seen by the following table:

Less Important Antimony Minerals

Name.	Formula.	Antimony.	S.G.	Observations.
		%		
Dycrasite	Includes Ag_3Sb and Ag_6Sb	15·7	9·44–9·85	Silver ore
Miargyrite	$Ag_2S.Sb_2S_3$	41·2	5·1–5·3	,,
Pyrargyrite	$3Ag_2S.Sb_2S_3$	22·3	5·77–5·86	,,
Stephanite	$5Ag_2S.Sb_2S_3$	15·2	6·2–6·3	,,
Polybasite	$9Ag_2S.Sb_2S_3$	9·4	6·0–6·2	,,
Freieslebenite	$(PbAg_2)_5.Sb_4S_{11}$	25·5	6·2–6·4	,,
Berthierite	$FeS.Sb_2S_3$	56·6	4–4·3	Rare
Zinkenite	$PbS.Sb_2S_3$	41·8	5·3–5·35	,,
Jamesonite	$2PbS.Sb_2S_3$	29·5	5·5–6	,,
Boulangerite	$3PbS.Sb_2S_3$	22·8	5·75–6	,,
Meneghinite	$4PbS.Sb_2S_3$	18·6	6·34–6·43	,,
Kilbrickenite	$6PbS.Sb_2S_3$	13·6	6·407	,,
Bindheimite	$Pb_3Sb_2O_8 + H_2O(?)$	22·7	4·60–4·76	,,
Nadorite	$PbSb_2O_4.PbCl_2$	30·5	7·02	,,
Chalcostibite	$Cu_2S.Sb_2S_3$	48·5	4·75–5·0	,,
Guejarite	$Cu_2S.2Sb_2S_3$	57·8	5·03	,,
Tetrahedrite	$4Cu_2S.Sb_2S_3$	24·8	4·75–4·9	Copper ore
Bournonite	$(PbCu_2)_3.Sb_2S_6$	24·7	5·7–5·9	,,
Famatinite	$3Cu_2S.Sb_2S_5$	27·4	4·57	,,
Barcenite	Doubtful	50·11	5·343	Mercury ore
Livingstonite	$HgS.2Sb_2S_3$	53·1	4·81	,,

Antimony also occurs in nature combined with arsenic, *e.g. allemontite* ($SbAs_3$); with nickel, *e.g. breithauptite* or *nickel antimonide* ($NiSb$), and *ulmannite* (NiS_2NiSb_2); with bismuth and lead in *kobellite* [$2PbS(BiSb)_2S_3$] and *taznite* (composition doubtful); with tin and lead in *franckeite* and *kylindrite* (*see* p. 88), but all these are very rare minerals.

Stibnite is by far the principal ore of antimony. The oxides are alteration products, and are usually found in small quantities at or near the surface, but senarmontite and valentinite are the chief ores at Sidi-Rgheiss and Sensa, respectively, in Algeria. The hydroxide, stibiconite, has been mined on a large scale at El Altar, Sonora, Mexico. Kermesite has been mined to a certain extent in Tuscany, Italy [6/1892, p. 21].

Native antimony, usually regarded as an alteration product, not infrequently occurs with stibnite, but usually in small quantities. It is abundant in the lower levels of the stibnite mine at West Gore, Nova Scotia, and predominates over stibnite in Wolfe Co., Quebec. It occurs massive, with a crust of oxide, near Armidale Co., Sandon, New South Wales, and in nodular masses, coated with oxide of antimony and clay at Erskine Creek, Kern Co., California [6/1893]. Native antimony occurs alone impregnating shales near Vinuela, Malaga, Spain, and in lumps up to 1 lb. in weight in the antimony veins and detritus of Bidi, British Borneo. A deposit of native antimony is said to occur 90 miles N.E. of Chang-Sha, Hunan Province, China.

Jamesonite is found alone impregnating schist in Southern Rhodesia; the same mineral, associated with silver, occurs in Hastings and Frontenac counties, Ontario. Jamesonite, tetrahedrite, stibnite and bournonite occur in small quantities with lead and zinc ores in some of the cross-veins of Cornwall. The two first minerals are associated together in the Foxdale lead mine, Isle of Man, and are the principal silver minerals in the Oruro silver-tin district, Oruro Department, Bolivia, whilst the same minerals, together with some stephanite, franckeite and kylindrite occur in Tatasi silver district, Potosí, Bolivia. It is interesting to know that tetrahedrite, rich in silver, occurs with jamesonite at Soana di Campiglia, Italy,

and that argentiferous jamesonite is associated with tetrahedrite at Santa Rosa, Santiago de Chuco, Peru. Jamesonite is associated with stibnite in Dumfriesshire, Scotland; in the Gwelo district, Southern Rhodesia, and at Böhsmdorf, S.W. Germany. Jamesonite, stibnite, zinkenite, bournonite and chalcostibite are found together near Wolfsberg, E. Harz, and the three first minerals occur together in Sevier Co., Arkansas. Jamesonite and boulangerite are found together in the silver-bearing lodes of Pribram, and jamesonite and berthierite occur with stibnite at Rosena, Czechoslovakia. Jamesonite, with some pyrite, arsenopyrite and other minerals, occurs in large quantities at Zimapan, Hidalgo, Mexico. Bindheimite, which is an alteration product of jamesonite, has been mined in the Arabia district, Nevada.

Stibnite, berthierite and bournonite, associated with silver occur with lead and zinc ores at Mobendorf, Saxony, Germany. Stibnite is associated with tetrahedrite near the Monarch Hill, Murchison Range, Transvaal; at Semnon, France, and in the Pulacayo silver district, Potosí, Bolivia, whilst these same minerals, together with bournonite, are found in the province of Castrovirreyna, Huancavelica, Peru.

Tetrahedrite and argentiferous galena are characteristic of some of the veins of Wheaton River area, Yukon, and tetrahedrite is not infrequently present in the silver-bearing veins of Mexico, Bolivia, Peru, etc.

The association of jamesonite with arsenopyrite has already been mentioned. Stibnite, realgar and orpiment are found together at Matra, Corsica, and at Allchar, Yugo-Slavia, and the two first minerals occur together at Monte Cristo, Snohomis Co., Washington. Stibnite and arsenopyrite are associated together in gold mines near Gatooma, Southern Rhodesia; in the Central Plateau, France; at Fairbanks, Alaska, and in Western Nevada. Native arsenic and realgar are sometimes associated with the antimony ores at Bidi, British Borneo.

Stibnite is associated with cinnabar at San Martino, Meria, Corsica; at Rohoncz, Hungary; at Selvena and other places south of Monte Amiata, Italy; at Cemernitsa and Prozer, Yugo-Slavia; at Tegora, British Borneo; near Kamloops Lake, British Columbia; in the Sandjak of Smyrna, Asia

Minor; at Djebel Tayo, Djebel Beba, Oued Ali and Sidi Rgheiss, Algeria; at Pulganbar, New South Wales; at Rio Blanco, Queretaro, Mexico, and in Alaska. Livingstonite and barcenite, associated with stibnite, have been mined on a large scale at Huitzuco, Guerrero, Mexico. Mercury was extracted from these ores, but no attempt was made to save the antimony.

Stibnite is associated with bismuth ores at Tasna, Bolivia, and at Huancavelica, Cerro de Pasco, Peru.

Nadorite, associated with lead and zinc ores, has been mined at Djebel Nador, Algeria.

Genesis and Classification of Antimony Deposits

A scientific classification of antimony deposits is hardly possible with the somewhat scant knowedge possessed of the majority of them. It has already been pointed out that in normal years the world's consumption of the metal is only a moderate one. In abnormal years there has been more or less energetic mining in many localities for the short periods during which the market was favourable. Not infrequently by the time geologists arrived to examine and report on the deposits, the workings were either under water or had caved in. Hence, although a few antimony deposits have been studied in detail, the majority of them have only been examined superficially, and of quite a number of them little or nothing of geological value is known.

One fact, however, stands out prominently—antimony ores, like those of mercury, are not infrequently associated with volcanism as opposed to plutonic igneous activity, and were deposited near the surface (*compare* Imperial Institute monograph, *Mercury Ores*, 1923, p. 2) at a comparatively low temperature and under moderate pressure. As instances of this one may quote the antimony deposits of the Monte Amiata region, Tuscany, Italy; of Southern Utah; of Thabyu, Amherst district, Burma; of the Bridge River area, British Columbia; of West Gore, Nova Scotia; Hsi-Ku'ang-Shan, China; and the unique mercury-antimony (livingstonite) deposits of Huitzuco, Mexico (*see Mercury Ores*, pp. 64–5).

On the other hand, it is highly probable that certain antimony minerals, particularly sulphantimonides, and in some instances stibnite, were deposited at intermediate depths under moderate temperatures, but strong pressures. Examples are the antimony minerals associated with native silver in the Cobalt district, Ontario; the stibnite deposits of Hillgrove, New South Wales; and the stibnite occurring in the Bendigo veins of Victoria. Other probable instances are the antimony ores (usually stibnite) of the gold-bearing replacement deposits in limestone of the Mercur district, Utah, and of the Black Hills, South Dakota; the antimony ores (usually tetrahedrite) of silver-lead veins at Slocan, British Columbia; Clausthal, Germany; Pribram, Czechoslovakia (with stibnite, boulangerite and pyrargyrite); and of certain silver-lead replacement deposits in limestone, *e.g.* at Eureka, Nevada (with stibnite); Park City, Utah; at Aspen, Colorado (with polybasite); and at Andreasberg, Hartz (with stibnite, breithauptite, pyrargyrite and polybasite).

Again, apparently antimony ores have occasionally been deposited at high temperatures, and under great pressures. Examples of this are the sporadic occurrences of jamesonite or stibnite in the tin-silver-tungsten-bismuth lodes of Bolivia; the somewhat argentiferous jamesonite deposit of Zimapan, Mexico; the silver-bearing bindheimite (after jamesonite) veins of the Arabia district, Nevada; and the stibnite of the normal quartz gold-bearing veins of Western Australia.

Antimony ores, like those of mercury, occur in rocks of all ages, from the pre-Cambrian to the Quaternary, and in various stratified and igneous rocks. In some deposits, like those of Hsi-K'uang-Shan, China, and West Gore, Nova Scotia, no igneous rocks have been observed either in or near them, whilst many antimony deposits appear to be intimately connected with eruptive rocks, *e.g.* the Bidi deposits of British Borneo; those of the Bridge River area, British Columbia; South Ham, Quebec; Wheaton River area, Yukon; Hillgrove district, New South Wales; Kostainik, Bela Reka, and Cemernitsa, Yugo-Slavia; Pan-hsi, Wu-shi, etc., China; La Sirena, Hidalgo, Mexico; as well as the antimony lodes

of Alaska; of Sevier Co., Arkansas; of Western Nevada, and of the departments of Junín, Huancavelica and Cuzco, Peru.

Antimony-bearing veins proper, as a rule, are only rich at and near the surface, or to a moderate depth below it, the antimony ore not infrequently being replaced at shallow depths by other ores or minerals. Thus blende appears to be replacing stibnite in Sevier Co., Arkansas; scheelite predominates in the lower levels at Su Suergiu, Sardinia; pyrite is replacing stibnite at the Djinlikaya mine, Asia Minor, and at the Chiang-hsi-lung mines, China; and quartz largely predominates over stibiconite even at very shallow depths in El Altar district, Sonora, Mexico.

Generally speaking, pure stibnite veins have not been followed beyond a few hundred feet in depth. Thus, the principal antimony-producing mines of New South Wales in the Hillgrove district were worked to a vertical depth between 200 and 300 ft. At Endeavour Inlet, New Zealand, antimony mining was successfully carried on between 400 and 500 ft. Some of the Chinese mines have been worked between 500 and 600 ft., and a few of those of the Central Plateau of France have been explored for an altitude of 1,000 ft., but in no instance have they been mined to anything like that depth in any one locality.

In auriferous stibnite quartz veins, the stibnite appears to extend to greater depths than those carrying pure stibnite alone. Thus at West Gore, Nova Scotia, a vein has been mined to a depth of 850 ft.; at Costerfield, near Bendigo, Victoria, auriferous stibnite has been followed down to a depth of 1,000 ft., and in the *filon Georges* of La Lucette, France, to nearly 1,000 ft. in depth.

In sporadic or sparsely distributed occurrences, antimony ore appears to go still deeper. Jamesonite is found at a depth of 876 ft. in granite in the Foxdale lead mine, Isle of Man. At the Cam and Motor mine, Gatooma, Southern Rhodesia, a small percentage of stibnite, together with some arsenopyrite, occurs in the auriferous quartz vein to the greatest depth yet reached (viz. 1,800 ft. in 1924). At the Phœnix mine, Sebakwe district, Southern Rhodesia, the ore contains on an

average 0·73% antimony, and is found impregnating the vein to the present depth of 2,300 ft.

The above appear to correspond to antimony deposits of shallow, intermediate and deep origin, respectively, already mentioned.

Antimony deposits may conveniently be classified as follows:

(1) *Fissure Veins of Stibnite with a Quartz Gangue.*—At and near the surface the stibnite may be replaced by antimony oxides. They are of two types:

(*a*) *Non-auriferous and non-argentiferous*; metalliferous associations few, generally pyrite only. Examples at: Freycenet and Mercœur, France; Panhsi, An-hua, Chiang-shi-lung, China; Kano, Japan; Bidi, British Borneo; Gatooma, Southern Rhodesia; York Co., New Brunswick; South Ham, Quebec; Endeavour Inlet, New Zealand. Reticulated veins or stockworks may be regarded as a variety. Examples occur in the Ribas Valley, Spain; at Prata, Portugal; and at Kantishna, Alaska.

(*b*) *Auriferous or argentiferous, or both*; associations arsenopyrite, pyrite and galena. In addition there may be blende, chalcopyrite, jamesonite, tetrahedrite, berthierite and other complex minerals. The gangue may be mixed with some calcite or dolomite. Examples at: Magurka, Czechoslovakia; La Lucette, France; West Gore, Nova Scotia; Wheaton River, Yukon; Fairbanks, Alaska; Quartzburg, Idaho; Chillagoe, Queensland; and Costerfield, Victoria.

(2) *Fault- or Shear-Zones in Limestone, Sandstone or Schist,* the ore being irregularly distributed along the zones in seams, pockets and bunches, or interbedded, usually in lenticular form. The gangue is usually scarce, and metalliferous associations are few or lacking. Examples at: Hoffnung, near Brück, Germany; Hsi-Ku'ang-Shan, China; Murchison Range (auriferous and argentiferous) and Barberton, Transvaal; Bridge River, British Columbia (auriferous).

(3) *Irregular Masses in Limestone, formed by Substitution.*—Gangue scarce or lacking; metalliferous associations few or wanting. Examples at: Cettine di Cotorniano, Italy; Su Suergiu, Sardinia; Kostainik and Allchar, Yugo-Slavia;

Sidi-Rgheiss, Djebel Bebar, Bou Zitoun and Djebel Nador, Algeria; Huitzuco, Guerrero and La Serena, Zimapan, Mexico. They sometimes form *contact deposits*, as at Kostainik, Allchar, Cottine di Cotorniano, and Sidi-Rgheiss.

(4) *Impregnations of Porous Beds of Limestone or Sandstone.*—Gangue and metalliferous associations scarce or lacking. Examples at: Armsberg field and Passauf mine, near Nuttlar, Westphalia, Germany; Southern Utah, United States.

(5) *Sporadic or Sparsely Distributed Occurrences.*—(*a*) In lead- and zinc-bearing veins; (*b*) in copper-bearing veins; (*c*) in mercury-bearing veins or deposits; (*d*) in gold-bearing quartz veins; and (*e*) in silver-bearing veins.

Mining of Antimony Ores

As a general rule the mining of antimony veins differs in no way from that of ordinary quartz veins containing base metals, and seldom presents any special difficulties. A few deposits are worked opencast. Of course where the ore occurs in the form of large irregular deposits, particular methods may have to be adopted, in order to win it economically.

The system of mining hitherto adopted in the Hunan Province, China, is without method. The ore is followed down and worked out as found, leaving irregular-shaped chambers, often of considerable size, without support. There is an almost total disregard for ventilation; native-made black powder is used for blasting, and vegetable oil flare lamps as illuminants. Each mine is let on contract, and the miners work on the piecework system. In 1916, arrangements were being made at the Wu-hsi mines for development on modern lines and for the installation of hoisting and pumping plants [7/p. 371].

Concentration of Antimony Ores

Stibnite has a low specific gravity (4·5); moreover it is very soft (H = 2) and friable, producing large quantities of slime when crushed, so that usually the losses with ordinary water concentration make treatment prohibitive, except, of course, when precious metals are present in the ore in payable quantities.

Antimony sulphide, like molybdenum sulphide, is amenable to flotation processes. Experiments on the froth flotation of stibnite ores are described by Daniels and Corey [8]. Their conclusions are that low-grade stibnite ores can be successfully concentrated by flotation methods to yield shipping concentrates. Fine grinding is necessary for the best recovery and highest grade of concentration. The creosote oils, with sulphuric acid, give the highest recoveries at the lowest cost of treatment. Re-treatment of primary flotation tailing will increase the total recovery.

The refractory antimonial gold ore of the Cam and Motor Gold Mining Co., Ltd., of Southern Rhodesia is now being concentrated by water and followed by oil-flotation. At the Phœnix mine, Southern Rhodesia, the gold ore contains on an average 0·73% antimony. The sand is discharged to dump, and allowed to weather; the slime is accumulated in dams, and allowed to dry. The surface of the slime is ploughed over at intervals of a few weeks. By this process partial oxidation by weathering takes place, the slime becoming amenable to cyaniding, and an extraction of 80% of its gold content is attained [9].

METALLURGY OF ANTIMONY

The metallurgy of antimony may be divided into: (1) Liquation processes; (2) Reduction of sulphide; (3) Simple roasting; (4) Volatilizing roasting; (5) Reduction of oxides; (6) Direct processes for low-grade ores.

(1) *Liquation to Crude Antimony.*—Ores containing more than 90% of the sulphide are considered to be "crude" antimony. Those containing more than 40 and less than 90% may be liquated for the production of crude antimony.

Intermittent liquation is usually conducted in pots or crucibles. In Europe, the pots are of fire-clay. They stand vertically in rows on fuel in an open fire. Each row is separated from the next by a brick wall. In the bottom of each pot are four or five holes for the escape of the molten sulphide into a burnt clay receiver placed below. In China, the only country where liquation is carried out on a large scale, two inclined earthenware pots are used with the axes at right

angles to each other. The upper pot is perforated at the lower end of the inclined bottom, in order that the molten sulphide can trickle continuously into the lower receiving pot [10/p. 257]. Two pairs of pots or crucibles are contained in a narrow furnace built of ordinary brick. The intermittent liquation process is a wasteful one, as the residue contains up to 15% antimony, or even more [11/p. 566]. Schoeller has shown that the crude material produced by this process always contains much less sulphur than is required by the formula Sb_2S_3. An analysis of Hunan product yielded the following percentages: Antimony, 73·56; sulphur, 22·45; oxygen, 3·18; iron, 0·70; insoluble, 0·05; the calculated composition being Sb_2S_3, 77·17; Sb_4O_6, 19·08; metallic antimony, 2·54; FeS, 1·10; insoluble, 0·05. In addition, an oxy-sulphide, Sb_4OS_5, is probably present [12] [10/p. 258].

For continuous working, tube furnaces, placed vertically over receivers, or reverberatory furnaces, with a tap-hole at the deepest point of the bed for the removal of the liquated sulphide, have been used.

(2) *Production of Metallic Antimony from Rich Stibnite (60% Antimony) or from Liquated Sulphide.*—This is known as the "precipitation" or "iron reduction" method, the reduction taking place according to the following equation:

$$Sb_2S_3 + 3Fe = 2Sb + 3FeS$$

The operation is carried out either in crucibles or in reverberatory furnaces. In the English process the crucibles, made of a mixture of fireclay and plumbago, are placed on the bed of a long reverberatory furnace, the reduction being in three stages:

(i) *Singling.*—The sulphide is reduced by wrought-iron scrap, the metal produced being known as "singles," having approximately the following percentages: Antimony, 91·63; iron, 7·23; sulphur, 0·82. Salt is added to the charge to assist in the separation of the slag and the fusion of the gangue.

(ii) *Doubling.*—The charge consists of "singles," a certain amount of liquated sulphide and common salt. The product is known as "star bowls," and contains antimony, 99·53; iron, 0·18; sulphur, 0·16%.

(iii) *Refining or Frenching.*—The "star bowls" are mixed with "antimony flux" and liquated sulphide, producing "star" antimony. The ingots are known in the trade as "French metal." The loss amounts to 10%, owing to volatilization. The fume given off is collected in condensing chambers [13] [11/p. 570].

In reverberatory furnace practice, there are two stages: (i) Fusion with scrap iron to produce crude metal; (ii) refining fusion.

(3) *Treatment of Poor Ores containing Stibnite, Antimony Oxides and Liquation Residues by Simple Roasting to the Tetroxide.*—This process need not be described here, being practically obsolete now, and in any case only adaptable to the poorest ores and liquation residues (5 to 20% antimony).

(4) *Treatment of Poor Ores, etc., by Volatilizing Roasting.*—The volatile oxide Sb_4O_6 (or Sb_2O_3) is produced according to the following equation:

$$2Sb_2S_3 + 9O_2 = Sb_4O_6 + 6SO_2.$$

This is usually effected in the Chatillon and Herrenschmidt plants. In the former, the roasting furnace consists of two large rectangular cupolas, charged with alternate layers of fuel and ore, which communicate with two lower and smaller ones, where hot air is produced, and where the last traces of the oxide are removed from the scoria. The condensing system consists of sheet-iron tanks and a filtration chamber or bag-house.

In the better-known Herrenschmidt plant, the roasting furnace is a rectangular shaft of fire-brick with a step-grate of iron bars. The upper part of the furnace communicates with a series of chambers provided with condensation pipes of corrugated iron, or of iron with projecting horizontal wings (*tuyaux à ailettes*), the air and dust being drawn through them by two exhaust fans. Beyond the condensing chamber is a coke-tower, water coming from which lays down the last trace of uncondensed oxide. The charge, when the furnace is hot, consists of 50 kg. ore (containing about 15 or 20% antimony) mixed with 2 kg. charcoal. Gas coke gives better results.

The temperature of the roasting should not exceed 400° C. The yield in oxide is said to be at least 90% of the metal contained in it [3/p. 98] [14].

(5) *Reduction of Antimony Oxides* (whether oxide ores or oxides produced in roasting (3) and (4), or the two mixed together).—This is generally effected in small reverberatory furnaces by carbon in the presence of alkaline fluxes, such as crude sodium carbonate (soda ash), sodium sulphate (salt cake), and sometimes common salt. Blast furnaces are occasionally used for low-grade ores. The flue of the furnace must be connected with a condensing system of chambers or pipes. As a rule, the metal must be refined in crucibles or in a reverberatory furnace [11/p. 581] [14].

(6) *Direct Processes for Low-grade Material.*—Schoeller has described [10/p. 244] the direct method of smelting in blast furnaces, suitable for stibnite, slag and liquation residues containing 25 to 40% antimony. The reduction is effected without iron. According to Schoeller [10/p. 254] the molten stibnite absorbs oxygen from the blast, giving trioxide, which is soluble in the sulphide; the oxide at once reacts with a further quantity of sulphide with the formation of metal and sulphur dioxide, thus:

$$(1)\ 2Sb_2S_3 + 9O_2 = Sb_4O_6 + 6SO_2$$
$$(2)\ Sb_4O_6 + Sb_2S_3 = 6Sb + 3SO_2$$

In order to reduce loss by volatilization, a tall shaft must be used, and the furnace must be connected with a suitable condenser.

Electrolytic Methods.—Various electrolytic methods of extracting antimony are described by Wang [3/pp. 124–30], but it appears none has been worked on a commercial scale. In order to obtain a smooth deposit of antimony it must be precipitated as a primary product of electrolysis. A hydrochloric acid solution of tartar emetic, known as the "tartrate bath," is commonly used for antimony-plating. By the addition of a small quantity of saturated aqueous solution of oil of bergamot to the electrolyte the smooth deposit does not peel off [13A].

PROPERTIES OF ANTIMONY

Antimony is a member of the natural family of elements which includes nitrogen, phosphorus, arsenic and bismuth. It is a silvery white, crystalline brittle metal, and has a high lustre. Its specific gravity is from 6·7 to 6·86. It melts at 630° C., boils at about 1300° C. and volatilizes at 1500° C. The specific heat is 0·0523. The coefficient of linear expansion is $11{\cdot}5 \times 10^6$ per 1° C. The electrical conductivity is 4·2 (silver = 100). The atomic weight is 120·2. Modifications of the metal are black antimony and yellow antimony, the latter corresponding to white phosphorus and yellow arsenic. Antimony has three valencies, 3, 4 and 5, and its chemical properties are very similar to those of arsenic. In other ways it stands close to the zinc group, particularly to the elements germanium and zinc. Antimony trioxide (Sb_4O_6 or Sb_2O_3), antimony tetroxide (Sb_2O_4) and antimony pentoxide (Sb_2O_5) are examples of compounds of 3, 4 and 5 valencies, respectively. The first two occur in nature. The last is formed during the oxidizing roasting of stibnite.

The chemistry of antimony is somehwat complicated (*see* [3/pp. 13–33]).

USES OF ANTIMONY

Metallic antimony, precipitated from an acid solution of antimony salts by metallic zinc in the form of a fine powder, is known as "iron black" (*Eisenschwarz*) or "antimonial black," and is used for producing the appearance of polished steel on articles made of papier-mâché or pottery, or for bronzing metals and gypsum.

The so-called *Goldschwefel* or pentasulphide (Sb_2S_5) is used in vulcanizing and colouring red rubber. Antimony trisulphide is used in making safety matches, and in certain paint pigments, *e.g.* vermilion of antimony or red sulphide, other colours being orange-red and orange-yellow. The trisulphide is also used in the lining of lead chambers for the manufacture of sulphuric acid [15/p. 8], and in pyrotechnics.

Other pigments are antimony yellow, including "Naples

yellow," antimony blue, used in the manufacture of artificial flowers, and antimony orange. Naples yellow is used in oil paints and in the glass and ceramic industries.

The oxide (mainly Sb_2O_4) is used for making opaque, white enamel and other sanitary ware, *e.g.* it is used as a substitute for tin oxide in making bath-tub enamels. The oxide (mainly Sb_2O_3) is used as a colouring agent in the manufacture of glass and pottery, and in the preparation of artificial gems. The preparation of various yellow pigments containing antimony for hard porcelain, stoneware or glazed earthenware is described by Wang [3/p. 170].

Antimony white paint can withstand the action of water, is as opaque as white lead, is scarcely acted upon by sulphurous fumes or sulphuretted hydrogen and is durable for outside-work painting [3/p. 155].

A pure white antimony oxide, known by the trade name "Timonox," is made by Messrs. Cookson & Co. in England. It is more readily wetted, and has a much lower oil absorption than zinc white [16]. In Victoria, Australia, the oxide produced in treating certain auriferous antimony ores is being utilized for the production of "Antox" paint.

The United States uses yearly about 2,000 tons of white oxides and 1,200 tons of sulphides, including vermilion and other colours [17/1921, p. 122].

Crocus of Antimony, a yellowish-red pigment, is obtained by melting 8 parts of the oxide with 2 parts of the sulphide. *Foie d'antimonie*, a dark-brown pigment, is obtained by melting 8 parts of oxide and 4 parts of sulphide together. *Kermes*, a brownish-yellow pigment, is made by melting a mixture of 5 parts of antimony sulphide and 3 parts of dry carbonate of soda.

The salts of antimony used as mordants are of two kinds, either basic or acid; the former is used for thickening, the latter for decolorizing. The mordants are tartar emetic (double tartrate of antimony and potassium), fluoride of antimony and oxychloride of antimony. The double fluorides of antimony and potassium or of antimony and sodium are used as substitutes for tartar emetic. The mordants are always used after the application of tannin, when they form

antimony tannates. Fluoride of antimony (SbF_3) is used as a mordant for dyeing.

Tartar emetic is used medicinally, antimony trioxide being employed in its preparation. In small doses tartar emetic seems to increase the activity of the function of secretion, particularly of the mucous membranes; in large doses it causes vomiting. It is also used in some eruptive or exanthematous fevers, in catarrhal affections, and as an ointment to be applied externally. "Antimonium sulphide" (Sb_2S_3) is used almost exclusively in veterinary practice as an alterative.

Liquated antimony sulphide is used in the primers of explosive shells. Antimony sulphide as a powder is used in the charge of some shells to produce on explosion a dense white smoke which is of service in range finding.

"Sugar of antimony" (powdered oxide ?) is used in making furniture polish, and *beurre d'antimonie* ($SbCl_3$) is used in rendering fireproof preservatives of wood, paper, and textile fabrics, such as creosote, pitch, tar and asphalt [17/1919, p. 291].

Antimonic acid ($HSbO_3 + 2H_2O$) has replaced arsenic acid in the manufacture of aniline yellow and aniline red.

Among miscellaneous uses are the following: The sulphochloride, used in medicine, or as a corrosive and macerating agent for wool; oxide of antimony, used in the manufacture of artistic lamp-shades and yellow opaque glass reflectors; antimony salts, particularly combined with fibrocol, as antiseptics for incorporation with lime-wash, and with the paste used in the *papiers couchés* of painters [3/pp. 167–74]. Antimony and bismuth are used in forming the couple of a delicate thermopile, which detects very small changes of temperature.

Alloys of Antimony

Alloys containing antimony are very numerous, but the useful alloys may be considered in the groups below:

(1) *Britannia Metal Alloys.*—These are sometimes called "white metal" in the United States, and are used in making cheap domestic tableware, as spoons, teapots, etc., cans, articles of luxury and toys. They are practically alloys of

tin and antimony in varied proportions with smaller quantities of copper, zinc, lead, bismuth or other metals. Copper, though present in comparatively small amounts, is an essential constituent of Britannia metal [21]. Together with antimony it makes the tin harder, tougher, more sonorous and more easily polished. Britannia metal has a silvery colour with a bluish tinge. Examples of these alloys are given in the following table:

Britannia Metals and Allied Alloys

	Antimony.	Tin.	Lead.	Copper.	Zinc.	Bismuth.
	%	%	%	%	%	%
Ashberry Metal [1]	15·0	79	—	3·0	2·0	1·0 [2]
Britannia „ (English)	5·0	94	—	1·0	—	—
„ „ sheet	7·80	90·6	—	1·6	—	—
„ „ cast	9·2	90·6	—	0·2	—	—
English plate-pewter	10	80	1·0	9·0	—	—
German „	24	72	—	4·0	—	—
Minofor Metal [1]	18·2	68·5	—	3·3	10·0	—
Pewter	7·0	89·4	1·8	1·8	—	—
Prince's Metal (for covers)	15·25	84·75	—	—	—	—
Queen's Metal	7·1	88·5	—	3·50	0·9	—
„ „ (teapots)	8·88	73·36	8·88	—	—	8·88
Wagner's „ (fine)	9·66	85·64	—	0·81	3·06	0·83

[1] Employed for making forks, spoons, coffee-pots, teapots, etc. Harder than Britannia metal, but less beautiful. [2] Nickel.

[19] [20] [21].

(2) *Bearing or Anti-Friction Metals.*—These are frequently called "white metal" in England. They are in great variety and generally consist of varied proportions of tin, antimony and copper; rarely of antimony, zinc and copper. A white-metal bearing enables an axle to run with extreme smoothness. The hardness of the alloy depends on the amount of copper present. It is not suitable for heavy loads, but only for light and medium loads. A few white metals consist largely of lead, alloyed with antimony, and generally some tin. Examples of such alloys are given in the following table:

Anti-Friction or White Metals for Bearings

	Antimony.	Tin.	Lead.	Copper.
	%	%	%	%
Admiralty and German (light loads)	10	85	—	5
Admiralty special	9	83	—	8
Austrian Government (railroads)	7	90	—	3
Automobile bearings (French)	15	10	75	—
Babbitt Metal	7·5	89	—	3·5
" " (hard)	8·3	83·3	—	8·3
British (medium loads)	15·5	76·7	—	7·8
" (heavy axles)	18·2	72·7	—	9·1
" (rapidly revolving axles)	77	17	—	6
Dandelion Metal (Penn. R.R. U.S.A.)	18	10	72	—
Gas-engine bearings	10	15	75	—
German (heavy loads)	8	90	—	2
Great Eastern Railway (medium)	15·5	76·7	—	7·8
Magnolia Metal	15	5	80	—
" " (spindles)	16·25	5·25	78·25	0·25
" " (high-speed shafting)	15	8	76·5	0·5
" " (dynamo bearings)	15	12	72	1
Prussia (railroads)	6	91	—	3
Street-car motor bearings	10	85	—	5
White metal (pivot bearings)	12·08	—	87·92	—

[19] [20] [21].

(3) *Type Metals.*—These are essentially alloys of lead, antimony and tin, with, occasionally, copper and bismuth. The last metal sometimes replaces tin in the alloy. The effect of the antimony is to harden the alloy, and to impart the property of slight expansion on solidification, thereby yielding perfect letters. Examples are given in the following table:

Standard Type-Metals

	Antimony.	Tin.	Lead.
	%	%	%
Standard electrotype	4	3	93
" linotype	12	5	83
" monotype	18	8	74
" stereotype	13	4.50	82.50
Ordinary linotype	13	5	82
Cheap "	11	3.50	85

[21/p. 510].

(4) *Hard or Antimonial Leads.*—These are suitable for any technical purpose in which the lead, when used alone, possesses too low a melting point. Antimonial lead, carrying upwards of 5% antimony, is employed in the manufacture of shrapnel bullets. Low-grade antimonial lead is used to a large extent in storage batteries, and as sheet lead in acid chambers; it is also used for cocks and valves that come in contact with acids in chemical works. Hard or antimonial lead is a by-product of lead smelting, and for the 10 years preceding the Great War the production of antimonial lead in the United States ranged from 10,000 to 15,000 tons per annum, one-third of this amount being produced from imported ore.

(5) *Miscellaneous Alloys of Less Importance.*—Amongst these are battery plates, with 6% antimony and 94% lead; ship's-nail alloy, composed of 17% antimony, 50% tin and 33% lead; alloys used in the manufacture of metallic mirrors, buttons, etc.; Cook's alloys, which are compounds of antimony and zinc, and which can be used for the production of pure hydrogen in the laboratory; alloys of antimony and gold, used in jewellery; regulus of Venus, an alloy of a beautiful violet colour, formed of equal parts of antimony and copper, and which, in combination with tin, is used in the industries; an alloy of lead and antimony used in making dice-boxes, etc.; and a lead-antimony alloy which is coming into use for the sheathing of electric cables.

Marketing of Antimony Ores and Metal

In England sulphide antimony ore or stibnite is usually bought at so much per unit. Thus, on April 18, 1916, the price was 11*s.* per unit, less 2½%. In 1919–21, it was 3*s.*, 4*s.* and 2*s.* 6*d.* per unit, with regulus or refined metal at £45 8*s.*, £60 2*s.* and £38 18*s.* per ton respectively [22].

On the Continent various formulæ are used in the purchase of antimony ores. American buyers commonly make a basis of $1 per unit (22·4 lb.), with metal at 8 cents per lb., and the ore containing about 50% antimony, with a variation of one-third of the difference in the market price for the metal per 2,240 lb., up or down [3/p. 197].

With regard to penalties, in England early in 1916 they

were as follow: Lead, up to 0·3% free, with an allowance to buyers of 5*s.* per ton of ore for every one-tenth of 1% over 0·3% up to 1½%; arsenic, 0·1% free, with an allowance to buyers of 7*s.* 6*d.* per ton of ore for every one-tenth of 1% in excess of 0·1% up to 0·5%. Should the ore fall below 60% in antimony content, an allowance to be made to buyers of 3*d.* per unit down to 55%. If below 55% and down to 50% an allowance of 6*d.* per unit. If above 60% an allowance to be made to sellers of 3*d.* per unit [23/p. 23]. Copper carries the same deductions as arsenic. Zinc and bismuth should not be present in more than traces [23A].

Antimony is marketed (1) as "regulus" or refined metal usually containing upwards of 99% antimony, in the form of cakes or discs, or of fragments of them, the solidified surface being covered with a fern-like appearance produced by allowing the molten metal to solidify slowly beneath a layer of slag. This is "star metal" or "star antimony," and is considered the finest quality of refined antimony; (2) as antimony "crude" or "crude" or "needle antimony," which is simply the liquated sulphide.

The commercial brands of antimony are as follow: A.S.P., St. Helen's Smelting Co., Manchester; C., Cookson and Co., Newcastle-on-Tyne; H., Hallett and Son, London; Tyne, Cookson and Co., Newcastle-on-Tyne; W.C.C., Wah Chang Trading Corporation, Chang-Sha, China; Lucette Brioude, La Société Franco-Italienne, Brioude, France (Quin's *Metal-Handbook and Statistics*, 1924, p. 166).

The London prices of antimony from 1918 to 1923 are shown in the following table:

Highest and Lowest London Prices of Antimony [1]

(In £ sterling per ton of 2,240 lb.)

	1918.		1919.		1920.		1921.		1922.		1923.	
	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.
English regulus	85	80	55	40	72	45	45	34	36	25¾	36	27½
Chinese regulus	82	60	53	35	70	34	33	23	26	23½	36	24½
Crude . .	70	57½	50	29	56	25	19	17	18½	14	24	17

[1] *Metal Prices and Statistics*, 1922, p. 17, and *The Ironmonger*.

The average prices in New York from 1908 to 1923 are shown in the following table:

Average Prices of Antimony in New York

(Cents per lb.)

Brands.	1908–1913 (average).	1914.	1915.	1916.	1917.[1]	1918.	1919.	1920.	1921.	1922.	1923.
Cookson's .	8·45	10·50	24·48[2]								
Hallett's .	8·13	9·82	22·30[2]								
Chinese and Japanese ordinary . .	7·49	8·53	29·52	25·33	20·73	12·58	8·19	8·49	4·96	5·47[3]	7·9

[1] To 1917, from *Metal Statistics*, 1918, pp. 359, 361 and 365. From 1918 to 1923, from *Mineral Industry*.

[2] Jan. to April only. No transactions recorded afterwards during the war.

[3] During Sept. 1922 a duty of 2 cents per lb. was put on antimony, as against the previous rate of 10% *ad valorem* (equiv. to 0·35 c. per lb.).

Early in the Great War the British Government placed an embargo on antimony. In the United States the price of the metal in 1915 reached or exceeded 40 cents per lb., but early in 1917 it had dropped to about half. By 1919 and 1920, prices were about normal again, but in 1921 and 1922 they fell to about 5 cents per lb. However, in 1923 prices were normal again and were rising in 1924. Thus on March 22, 1924, Cookson's "C" grade was quoted at 15 cents; W.C.C. brand at 13½ cents, and Chinese and Japanese ordinary brands at 11¼–11½ cents.

World's Production of Antimony

As far as the information available permits, the production of antimony ore in the different countries of the world is given in terms of metal in the table on page 24.

World's Production of Antimony Ore

(Metal Content in Metric Tons)

Producing Country.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
British Empire :											
Great Britain [1]	—	—	4	4	2	4	—	—	—	—	
British Borneo [2]	—	435	175	—	—	—	—	—	—	—	
India [3]	—	—	6	520	65	—	3½	¼	¾	—	
British South Africa [4]	26	—	40	344	286	51	14	5	—	—	
Canada [5]	—	—	536	354	144	—	—	—	—	—	
Australia [6]	1,270	1,237	2,000	2,047	1,422	779	649	581	236	641	
Total British	1,296	1,672	2,761	3,269	1,919	834	666½	586¼	236¾	641	
Foreign Countries : [7]											
Austria-Hungary	1,878	—	—	—	444	—	78 [8]	314 [8]	—	172	78
Czechoslovakia	—	—	—	—	—	—	287	613	—	—	
France	4,472	673	1,116	3,033	2,942	1,650	1,248	1,412	1,321	814	543
Germany	—	—	700	—	—	—	—	644	—	—	
Greece	—	—	—	—	—	—	67	61	—	—	
Italy	360	138	720	4,334	960	404	12	234 [8]	94 [8]	183	660
Portugal	10	—	—	1,000	—	—	—	—	—	—	
Serbia (Yugo-Slavia)	250	—	—	—	725	—	—	831	—	—	
Spain	—	—	100	170	160	20	—	—	—	—	
Asia Minor	240	330 [9]	42 [9]	—	400	400	400	400	400	—	
China [10]	13,032	19,647	23,357	42,800	31,000 [9]	18,112 [9]	8,923 [9]	15,998 [9]	14,752 [9]	14,316 [9]	
Japan	20	32	180	280	8	41	1	—	—	—	
Indo-China	—	—	160	642	600	—	—	—	—	—	
Algeria [10]	186	320	2,740	8,940	4,550	2,218	723	1,000	103	530	
Mexico	2,340	1,570	200	829	2,647	3,269	470 [8]	623 [8]	45 [8]	457	
United States	—	—	1,760	1,420	310	45	—	—	—	20	40
Argentina	—	—	—	—	812	360	28 [8]	50 [8]	—	—	
Bolivia	30	102	9,859	15,077	12,860	4,770	127 [8]	587 [8]	341 [8]	—	
Peru	—	—	260	930	450	160	38 [8]	10 [8]	9 [8]	—	
Total Foreign	22,818	22,812	41,194	80,180	58,143	31,449	12,402	22,777	17,065	—	
Grand Total	24,114	24,484	43,955	83,449	60,062	32,283	13,068½	23,363¼	17,301¾	—	

1 *Home Office, Mines and Quarries, Gen. Rept. with Statistics*, Pt. III, *Output*.
2 *Imperial Inst., Bull.* **14**, 1916, p. 397 (Est. with ore = 50% antimony).
3 *Geol. Survey, India, Rec.* (ore = 50% antimony).
4 *Union of South Africa, Dept. Mines and Indus., Ann. Repts.* and *Southern Rhodesia, Sec. Mines Repts.* (ore = 50% antimony).
5 *Canada, Dom. Bur. Statistics* (concentrates = 40% antimony).
6 *Western Australia, Dept. Mines, Mining Statistics* (concentrates = 50% antimony).
7 *U.S. Geol. Survey Min. Res. of U.S.*, Pt. I, 1918 to 1922.
8 *Imp. Min. Res. Bureau, Antimony* (*Statistics*, 1919–1921).
9 *Mineral Industry*.
10 *Exports*.

CHAPTER II

SOURCES OF SUPPLY OF ANTIMONY ORES

(*a*) BRITISH EMPIRE

EUROPE

British Isles

England.—No antimony ore appears to have been raised from Great Britain since 1893. From 1774 to 1893 the total recorded output amounted to about 550 tons. Although economically of little importance, some of the occurrences are interesting from a geological point of view.

According to Henwood [24/p. 271], antimony ores, like those of cobalt, have been met with in a few cross-veins in Cornwall. This appears to have been the case at Wheal Boys, Endellion, which, according to Pryce [25], produced 95 tons of antimony ore between 1774 and 1776. In 1778 there were antimony works on Restronguet Creek, Falmouth Estuary [26]. Wheal Boys was reopened in 1906, and was found to be 180 ft. in depth. The lode, which was up to 4 ft. in width, contained bunches of ore, consisting of a mixture of jamesonite and stibnite, together with some blende and argentiferous galena. In depth the ore changes into galena. In ground recently prospected three quartz veins were found traversing calcareous shales, and containing bournonite, jamesonite and antimony ochre. Jamesonite was found to occur in pockets in the old Bodannon mine, Endellion. The lode, which strikes N.E. and dips N.W., yielded 4 tons of antimony ore in 1884.

In the Rose mine, Endellion, now idle, the vein strikes E.-W., and consists mainly of jamesonite with nodules of

bournonite in the gossan. The country rock is Upper Devonian slate, and at a depth of 120 ft. the lode is low in grade. In the Poltreworgy mine, Endellion, now idle, the lode of which courses N.-S. and dips E., jamesonite was found to a depth of 100 ft. from surface, and was succeeded by stibnite. At the bottom of the mine the ore was in veins less than 1 in. thick, and separated by a foot or two of country rock (killas) [27].

Jamesonite in lenticles up to 2 ft. in length, lying in gossan, occurs in the Trevinnick mine, St. Kew. The lode strikes N.-S., and dips W. It was being exploited in 1919. Besides jamesonite, the antimony lode carries stibnite, antimony-ochre, antimonial silver and gold, argentiferous galena, some pyromorphite, blende and siderite. Recent assays gave: Antimony 33%; lead 37%; iron 1%; sulphur 17%; silver 6 oz. and gold 2 dwt. per ton. The deep adit lies 250 ft. below the working adit. The outputs in 1876, 1892 and 1893 were 6 tons of antimony ore. There are said to be 1,500 tons of antimony ore blocked out, and several tons of dressed ore on the old floors.

The Treore mine, St. Teath, was being worked for arsenic in 1919. The lode strikes N.N.E., dips S.E. 70°, and averages 2 ft. in width. Besides arsenopyrite, it contains some lenticles of jamesonite and stibnite and needles of stibnite in quartz, siderite, chalcopyrite, galena and gold (1 to 3 dwt. per ton). The country rock is black slate of Upper Devonian age. The ore assays 35% antimony. The lowest level is 54 ft. below adit.

Among the lodes characterized by stibnite without jamesonite, the Pengenna, St. Teath, and the Trenute mines, Lezant, may be mentioned. In the former, the lode strikes N.W., dips S.W. 50°, and averages 4½ ft. in width. The stibnite occurred as veins, stringers and lenticular masses in killas, and sometimes also in a quartz gangue. It was succeeded by galena at a depth of 240 ft. About 16 tons of ore were produced in 1861 and 1862. There are some old smelting works near the adit-mouth. At Trenute, Lezant, the lode courses N.-S., dips E., and is from 3 to 5 ft. wide. It consists of stibnite (often forming nodules embedded in quartz) accom-

panied by siderite, blende, pyrite and calcite. The country rock is formed of grits and shale (Carboniferous). The workings, which extend to a depth of 30 ft. only, were suspended in 1919.

Other mines which have contained antimony ore are Penhale mine, St. Breock; Pillaton mine, Pillaton, which from 1819 to 1821 produced 132 tons of ore; Pentire mine, St. Minver Highlands; Pendoggett mine, St. Kew; Tredinnick mine, St. Erney; Fowey Consols mine, Tywardraeth; Reperry mine, Lanwet; Wheal Emily (east of Knighton) and one of the lodes of the Botallack mine, St. Just [27/p. 50].

The Herod's Foot mine, Lanreath, was on a cross-course from which a good deal of lead was raised, much of it rich in silver. The lode is described as carrying stibnite, bournonite, and small amounts of chalcopyrite, pyrite and blende [28/p. 396] and tetrahedrite [27/p.53.]

Antimony is stated to have been obtained near Hennock and Bovey Tracy, in Devon [26].

In the Lake District, Cumberland, stibnite has been found at the Robin Hood mine, Bassenthwaite, and at the Wanthwaite mine.

In Derbyshire, an antimoniated ore of lead is said to have occurred at Eyam and Ashover [27/p. 54].

In the Isle of Man, stibnite occurred as a small pocket near Niarbyl Bay, and the Foxdale mine contained small quantities of jamesonite, associated with fine-grained galena in the Great Lode coursing through the killas and overlying granite. Tetrahedrite also occurs in the mine. Jamesonite was found at a depth of 516 ft. in killas in the west and at 876 ft. in granite in the east.

Scotland.—According to G. V. Wilson [27/p. 54–6] the antimony vein of the Louisa mine of the Glendinning Antimony Mining Co., Dumfriesshire, Scotland, was discovered in 1760, and was regularly worked in 1793. From 1793 to 1798, 100 tons of antimony ore were raised, which sold for £8,400. The ore was smelted near the mine. The mine was reworked from 1888 to 1891, during which period about 88½ tons of metal were extracted. The mine has been reopened recently. The vein runs N.E., and is vertical or dips S.E. 80°. The walls are

horizontally slickensided, and about 4 ft. apart. The vein stuff consists mainly of a crush-breccia of slate (Silurian cemented by calcite and quartz, with occasional stringers of ore up to 2 in. wide. The ore is pockety, ranging from 14 and 20 in in thickness. The primary ores are stibnite, galena, jamesonite blende and chalcopyrite in small amount. The breccia forms the gangue, with a little quartz, calcite and barytes. Picked samples of stibnite yield antimony, 70%, and lead, 1%, and picked samples of galena, lead, 75%, and antimony, 1%. The secondary minerals are kermesite, valentinite and cervantite. The mine has been worked by levels, connected by shafts and winzes, but the actual vertical depth attained is not stated.

According to J. S. Flett [27/p. 56], the Knipes antimony mine (altitude, 1,700 ft.) is near the centre of a small granite-mass which rises through Silurian strata, forming Hare Hill, and the Knipe, Ayrshire. The vein, 12 to 18 in. wide, runs nearly N.–S., and is practically vertical. It consists of white quartz penetrated by needles of stibnite with crusts of yellowish antimony ochre. The old workings consist merely of a level driven from 30 to 50 ft. into the face of the hill.

Ireland.—In a few Irish lead mines the ore is recorded as being antimonial, but apparently stibnite has been actually raised only from the Clonibret mines, Co. Monaghan, where it was associated with galena. In 1845, the vein was described as "about 4 in. thick, with a bedding of quartz" in Silurian slates. The workings did not exceed a depth of 42 ft. No output appears to have been recorded, but it is stated that the enterprise reaped little profit. The mine was reopened under Government advice in 1917, and is included in the Home Office "List of Mines" for 1918, but not in that for 1919, so the presumption is that the workings had by that date been abandoned.

The mixed lead and zinc ore ("bluestone") of Connary is said to have contained stibnite, but in several analyses of "bluestone" which have been published, antimony is not included.

The rare antimony mineral kilbrickenite was discovered by Apjohn in 1840 in the lead mine at Kilbricken, Co. Clare [29].

ASIA

British Borneo

The island of Borneo was for many years one of the chief sources of antimony, but for the last 40 years or so the production has been relatively small, owing to the exhaustion of the principal mines.

Antimony was discovered in Sarawak by the natives nearly 100 years ago. It occurred in workable quantities at Bidi, Busan, Jambusan, Piat, Orogo and Siktingit, and in the basin of the River Rejang (Kanowit and Silalang).

At Bidi, according to Gröder [30/p. 415], clay-slates, alternating with sandstones, are in places underlain by a dark limestone. Antimony-quartz veins are said to cut through both limestone and slate. There are eruptive rocks consisting of porphyry dykes, and white and dark quartzose rocks. The ore is connected with these eruptives, especially with the quartzose rocks in which it often appears in needles or in coarse grains. Near the ore-bearing dykes, the limestone is crystalline. In some cases the irregular fissures expand into cavernous spaces, open in many places, or filled with stones and round pieces of ore. Besides veins, loose pieces of ore are found in the soil round the hills, mostly near the outcrop of the veins. Isolated masses occur in clay. By atmospheric degradation of the matrix these were sometimes left perched on pillars, like the well-known earth pyramids, and ladders were required in order to reach them [6/1892, p. 21]. A good deal of ore has been raised from such alluvium or detritus. The gangue of the veins is described by Everett [30/p. 416] as being felsitic, but is sometimes calcareous and then rich in ore. The white felsitic vein-stuff sometimes passes over into a grey, hard, felsitic mass with which the ore appears to be intimately mixed. The vein-stuff consists of stibnite, calcite, cerussite ("black spar"), in part intimately mixed, but the composition is very varied. The veins at Bidi dip at a high angle. In the Busan Hills, they strike N.W.–S.E. and dip N.E. 20° to 50°. In the Jambusan Hills the strike is E.–W.

The stibnite occurs in prismatic and fibrous masses and is non-auriferous. It is quite pure or mixed with quartz. Some

of it is altered to valentinite and stibiconite. Kermesite is also found. Native antimony occurs scattered in the gangue of the stibnite veins, in cavities of the limestone and in the alluvium (detritus). It is most plentiful in the Busan Hills. Pieces weighing as much as 1 lb. have been found. It has a granular and laminated structure, and a pure tin-white colour. The rare mineral *sarawakite* occurs as minute crystals in the native antimony. It is colourless or wine-yellow to greenish-yellow. It is suggested that it may be an antimony chloride. Associated more rarely with the antimony ore are copper, native arsenic, realgar, and gold [30/p. 416]. At Tegora stibnite is associated with cinnabar [31/1, p. 774].

According to Crocker's data, 25,000 tons of antimony ore of the value of more than a million dollars were raised for the Borneo Co. between 1859 and 1879. From 1864 to 1877, or in 14 years, 16,741 tons of antimony ore, sulphide and oxide, were exported, of value £667,795. This gives an average annual production of 1,196 tons. From 1876 to 1886, or in nine years, the tonnage is not given, but the value is stated to be £495,909. Assuming the value to be the same as that of the first period, this would represent 12,434 tons, an average of 1,381 tons per annum. The best years of the first period were from 1868 to 1875, inclusive; and of the second period from 1878 to 1884, inclusive [30/p. 418].

In 1894 and 1895, the production is stated to have been 599 and 657 tons of ore respectively, and in 1914 and 1915, 870 and 350 tons respectively [28/p. 397]. From 1915, no production appears to have been recorded.

India

Mysore.—Small quantities of stibnite and antimony ochre are found in veins and patches in a quartzose rock in the schists at Chikkannanahalli, Chitaldrug, State of Mysore. The veins are about 2 in. in thickness, swelling in places up to 12 in. or so in width. The ore is low in grade [32/p. 3].

Madras.—Crystals of stibnite are disseminated among the schists of the Sandur Hills, near Ramandrug, Madras [33/p. 12]. Good stibnite is found at Kodur, 2 miles from Chipurapilly, Vizagapatam [34/p. 164].

Bihar and Orissa.—Antimony ore is associated with galena at Hisatu, Hazaribagh, Bihar and Orissa, an analysis of picked ore showing 12% antimony [33/p. 11].

Baluchistan.—Antimony is associated with lead in the ancient lead mines of Shekran, Baluchistan [33/p. 10].

Punjab.—At the lower end of the Shigri glacier, S.E. of Kashmir in the Province of Lahaoul, Punjab, some half-dozen veins of antimony ore occur in granitoid gneiss in the Himalayas, at an altitude of 13,500 ft. One lode is described as being 10 to 40 ft. in width, and consisting largely of stibnite, cervantite and kermesite. Associated with the stibnite are small quantities of blende, galena, pyrite and manganiferous siderite. Some prospecting was carried out here at about 1850, and in 1905, about 15 tons of ore were shipped to England from these deposits. The veins are in an inaccessible position, and mining can only be carried on for about three months in the year [33/p. 13] [32/p. 3]. Stibnite, associated with pyrite, has been found in the Kangra district, Spiti.

N.W. Frontier Provinces.—Good antimony ore occurs in the Peshawur district, at Bajaur [34/p. 166].

Burma.—The most promising deposits of antimony ore in India are those in the Amherst district and the Shan States of Burma.

Stibnite appears to be generally distributed through the sandstones of the "older formation" of the *Amherst district.* Attempts to work the deposits were made as long ago as 1860. In 1885, a quarry was being opened in search of the ore at Lekka Taung, about 23 miles south of Maulmain. Here, according to Criper [35], stibnite and cervantite occur in pockets in a whitish quartzose sandstone. The deposits are generally found in or by the side of dykes, or rather fissures, traversing the yellow sandstone of the Amherst range. They are filled with a whitish quartzose rock, and usually have well-defined walls. The pockets are isolated. The richest ore is in the centre, where it may contain 79% antimony. Towards the edge the amount decreases to 2 or 3% only. Each deposit yields a few tons of ore.

The antimony lodes of Thabyu, Amherst district, have been described by Heron [36]. The quartz-antimony veins occur

in black slates, striking W.N.W., and dipping S.S.W. 40°–70°. The biggest lode is 20 ft. wide and traceable for 600 ft. The ore is stibnite, in bunches of radiating or parallel crystals up to 5 in. long and in massive aggregates coated to a depth of several inches with cervantite or stibiconite. The gangue is a yellow and white calcareous chert, showing distinct brecciation and often a cellular structure. Small angular fragments of slate are of frequent occurrence in the lode. Heron is of opinion that the Thabyu deposits are typical of the majority of stibnite occurrences, and were deposited from water at a comparatively low temperature and at a moderate depth from surface. The only deposit worked is a N.–S. vertical vein, having a main ore-body 3 ft. wide. On each side of this, 10 ft. of vein-stuff is exposed carrying patches of ore, with the walls of the lode not yet showing. Two analyses yielded 60·45 and 61·59% antimony. About 50 tons of antimony ore are said to have been exported from the area a few years before the war, presumably from loose boulders. For about three years during the war about 15 tons of ore were won from boulders and outcrops. The cost of mining and transport to the United Kingdom is given at 200 to 250 rupees per ton of ore.

A few of the antimony deposits of the *Southern Shan States* have been described by H. C. Jones [37].

The Naking deposit in the Möng-Hsu State appears to be the most promising one. The deposit—presumably a vein—is irregularly distributed along a N.–S. line, but the ore as exposed is too low in grade to be of much value. The country rock appears to be a purple sandy shale and purplish white sandstone. The tops of most of the hills are of Plateau limestone.

Close to the village of Möng-Ing, in the *Kengtung State*, there is a small vein or pocket of antimony ore in limestone. At Lebyin there occurs a small fine-grained quartz vein with sparsely disseminated stibnite.

In 1908 and 1909, Burma produced 1,000 tons and 2½ tons of antimony ore, respectively, all from the Southern Shan States. The former quantity is stated to have come from the Möng-Hsu State. Most of the ore was won from detrital boulders.

Stibnite is also said to occur in the *Northern Shan States* [38] [39].

Stibnite is also found in quartz veins in the *Thaton* and *Mergui* districts. The ore occurs in association with the intrusive granite of Tenasserim, or in the sedimentary rocks close to the granite contact.

Antimonial lead containing from 15 to 20% antimony is produced as a by-product at the Nam Tu smelters of the Burma Corporation, Ltd. Early in 1918, the company exported 450 tons of antimonial lead containing 13·4% antimony with some copper and silver [32/p. 2].

In 1916 and 1917, India produced 1,040 and 130 long tons of stibnite, respectively, most of which came from the Amherst district, Burma.

AFRICA

Southern Rhodesia

For some years there has been a very small production of antimony from Southern Rhodesia.

Antimony ore is distributed through a belt of country extending from Hartley to Belingwe and from Gwelo to Selukwe; in this belt it occurs most abundantly around Gatooma, Que Que and Lower Gwelo. It occurs sporadically in gold-bearing quartz veins and schistose lodes as stibnite, with a granular texture in the form of stringers, patches and large pockets, or disseminated through a schistose lode in the form of minute crystals of jamesonite [23/p. 22]. In the Cam and Motor mine, near Gatooma, the gold ore contains both stibnite and arsenopyrite. In the year ending June 20, 1917, 9 tons of antimony were sold as a by-product from this mine [40]. Stibnite and jamesonite occur in quantity in the Phœnix mine, at Que Que, and in the Sabiwa mine stibnite occurs with arsenopyrite [41].

Stibnite in Southern Rhodesia also forms definite veins, sometimes free from quartz. It has a coarsely bladed structure and contains no gold. A vein of this type, explored in 1916, occurs near Gatooma. It is 6 in. in width, strikes N.–S. and dips W. 60° [23/p. 22].

UNION OF SOUTH AFRICA

The Union of South Africa has produced a little antimony from time to time, especially during the war period, the total value of the production to the end of 1919 being £33,279 [42]. From 1915 to 1919, inclusive, the output was 1,559 short tons of antimony—all from the Transvaal. The best years were 1916 and 1917, with 721½ and 616½ tons, respectively. From 1920 to 1922, inclusive, there was no production.

South-West Africa.—At Otavi, in Damaraland, stibnite occurs with extensive deposits of galena and copper ores in carboniferous limestone [43].

Transvaal.—The Murchison Range, Pietersburg district, Eastern Transvaal, is made up of a long and narrow zone of schistose rocks bounded on the north, south and east by granite and gneiss. The range trends in a general E.-W. direction, and along it are two more or less parallel well-defined mineralized belts; the northerly one is known as the antimony belt; the southerly one is chiefly noted for gold only. The antimony deposits of the northern belt occur in a string of kopjes (hills) which extend from north of Leydsdorp in a N.E. direction for 30 miles. The country-rock consists of much altered and compressed chloritic quartzites and quartz and clay-slates. The antimony occurs as grey crystalline stibnite, associated with light-coloured quartz, in lenticular interbedded veins varying from a few inches to 20 ft. in width, which dip with the country rock N. 80°. At and near the surface the stibnite is altered to a yellow oxide of antimony. The ore contains a notable quantity of gold and silver. The individual kopjes of the antimony line are separated from one another by transverse faults. At the Free-State mine, the stibnite occurs disseminated through a calcareous gangue, made up of calcite and dolomite, with a little green sericite and some secondary quartz [44] [45/p. 142].

According to Mellor [45/p. 149], carbonates occur locally only, the main reef consisting for the most part of coarse reef quartz (primary) mingled with calcite, dolomite and iron carbonates. Stibnite and gold occur throughout the vein, the

former in bunches and masses of considerable size, the latter occasionally visible in coarse grains in the quartz.

According to Hall [45/p. 145], the ore-bodies are intimately associated with large conspicuous masses of limestone or dolomitized quartz-schist. At the United Jack mine, a greyish dolomitic limestone is traversed by a coarse network of quartz veins containing disseminated patches of stibnite, sometimes concentrated into more conspicuous masses, and intermingled with white quartz. The ore contains an average of 12½% stibnite, and 7 to 8 dwt. gold per ton.

Farther east, a reef body, up to 9 ft. wide, is exposed in sheared greyish limestone with green partings. At the Weigel Gold Mining Co.'s property, an interbedded reef, 4 to 5 ft. wide, contains stibnite, gold and some copper. The poorer, more solid bodies of auriferous stibnite are partly altered to stibiconite [45/p. 145].

At Castle Kopjes is a large quartz reef, which was very rich in visible gold, and which sometimes contained a little stibnite [44/p. 48].

A reef considerably to the south of Monarch Hill consists of irregular veins, streaks or patches of tetrahedrite, carbonate of copper and stibnite associated with greyish-yellow masses of crystalline rhombohedral carbonates. A little south of Monarch Hill, the "antimony reef" occurs also associated with pale greenish, thinly bedded, more granular limestone. The reef consists of very coarse fresh lustrous crystalline veins, patches or streaks of stibnite and stibiconite, interrupted by irregular areas of coarse quartz [45/p. 146].

In the Barberton district, stibnite was mined in the Komati River valley in 1916 and 1917. The country rock is a soft, greyish, thickly bedded, massive dolomitic rock, containing stibnite in the form of a series of lenticular bodies more or less continuous with one another by means of narrower connecting veins. The strike is N.N.W and the width of antimony-bearing rock is 5 ft. To a depth of 30 ft. there is yellow oxide of antimony. The ore from the lower levels forms a heavy, massive rock made up of an evenly medium-grained crystalline aggregate of highly lustrous fresh silvery-grey stibnite crystals with more rounded outlines, and varied by small irregular

blebs of the yellow oxide. The poorer quality ore occurs alongside the outer portion of the rich deposit, and is a highly quartzose greyish rock relieved by irregular greenish streaks, and showing a little coarsely crystalline grey dolomite; this variety contains larger scattered pockets or small nests of crystalline lustrous stibnite. The normal country formation is a dirty greenish carbonate rock with very irregular stringers of opaque white quartz and sparingly distributed specks of pyrite [46].

During the Great War antimony was raised at the United Jack and Monarch Hill mines, Murchison Range, the latter of which mines possessed a smelter. Ore was also smelted to "star" antimony at the Komati Rivervalley deposit, Barberton district.

NORTH AMERICA

Canada

Canada has hitherto never been a large producer of antimony; the outputs of both ore and metal have been intermittent. From 1886 to 1910 inclusive, the total shipments of antimony ore and concentrate were 6,901½ tons, chiefly from Nova Scotia and New Brunswick. From 1911 to 1914 inclusive, there was no output. The Provinces of Nova Scotia and New Brunswick were again the chief producers in 1915, 1916 and 1917. Since 1917 there has been no production.

British Columbia.—The antimony deposits of the Bridge River area, Lillooet Mining Division of British Columbia, have been described by Drysdale [47] and McCann [48]. Stibnite occurs in quartz, the ore averaging in value 40 to 60% antimony, free from arsenic, zinc and lead, and carrying gold in amount from a trace to 12 dwt. per ton. The stibnite appears in small lenses or "pockets" and "nests" from the fraction of an inch up to 1 ft. in thickness, and mostly under 4 ft. in length. The lenses follow fissures and shear-zones in a belt extending along the western limit of the Bridge River anticline from Mt. McGillivray to Lake Yaughton and northward. The chief country rock is a black metabasalt of the Bridge River Series intruded by irregularly shaped masses of a light-

coloured diorite-porphyry altered to calcite, sericite and halloysite near the ore. One vein strikes N. 51° E. (magnetic) and dips from N.W. 70° to vertical. A narrow dyke of porphyry follows the hanging-wall for a short distance, and here ore rich in antimony, and gold ($10·40 per ton) was recovered. Near by, ore is scattered in lenses throughout a sheared diorite-porphyry dyke, the highest gold content (12 dwt. per ton) occurring on the hanging-wall side, where the vein is composed of Bridge River metabasalt.

Drysdale considers that the stibnite was deposited from hot ascending waters charged with igneous emanations connected with a Tertiary volcanic cycle. The decomposition and concentration of ore in nests and pockets probably took place at slight depth and moderate pressure. It is quite probable that cinnabar was deposited during the same solfataric stage of volcanism as the stibnite and associated gold. The occurrences are of small dimensions, and there appears to have been no actual output of antimony from this region.

In the Slocan district (Ainsworth, Slocan and Slocan City Mining Divisions), a large body of stibnite was found in the Alps and Altwas claims in the north fork of Carpenter Creek (altitude 7,700 ft.). The vein was 4 ft. wide and contained 65% antimony [49/1906, p. 141].

There were a few shipments of ore from these claims.

On North Island, on the N.W. corner of Graham Island, some ore carrying gold, silver and antimony was discovered in 1909 [49/1909, p. 72].

At Tatlayoko Lake, Nanaimo district, a good deal of stibnite, mixed with quartz, was found associated with gold and silver in a quartz vein cutting a network of basic dykes [49/1910, p. 156].

There has been a small shipment of antimony ore from the Chinook Mt. group, Kiokook Creek, near Kanaka.

Stibnite occurs associated with cinnabar in dolomite, near Kamloops Lake (*see* Imperial Institute monograph, *Mercury Ores*, 1923, p. 24). On the Briar Claim, stibnite and cinnabar occur in solid massive bands in dolomite. In this region the rich streaks of cinnabar are invariably associated with stibnite [50].

New Brunswick.—About 75 years ago stibnite was discovered in the slates and quartzites of Prince William, York Co., 25 miles west of Fredericton, near masses of granite and dolerite ("diabase"). The antimony-quartz veins varied from mere stringers to several feet in width. A small quantity of native antimony occurred with the stibnite. Attempts to smelt the ore locally failed, so it was shipped in a raw state. Work was abandoned in 1890. In 1907, the deposit was reworked and much ore was raised therefrom [51]. The deposit was mined during the war period, and the ore was smelted and refined at works near Lake George.

Nova Scotia.—The West Gore antimony deposits of Hants Co., Nova Scotia, have been described by Askwith [52], Malcolm [53] and others. There are three nearly parallel veins, striking N.W.-S.E. and dipping S.W. 85°, which occupy fault-planes in grey slates and quartzite, striking N.E. and dipping S.E. 45°. The country rock belongs to the upper, slate or Halifax division of the gold-bearing series of Nova Scotia, and is of Cambrian or Pre-Cambrian age. The principal vein has been traced on the surface for a length of over 1,200 ft. It varies from a few inches to 7 ft. in width. The vein-filling consists of crushed slate, calcite and quartz cut by a number of small quartz stringers from the foot-wall side, the foot-wall itself being irregular and indistinct. As a rule the ore lies on the hanging-wall, which is well-defined and smooth, but sometimes it occurs on both walls or follows the centre of the vein. The ore is stibnite, with a little native antimony, and is associated with arsenopyrite, pyrite and galena. The native antimony occurs throughout the ore zone in small stringers and bunches, and was quite abundant on the sixth level. The stibnite is sometimes solid and sometimes mixed with quartz, and often, when exposed, is covered with a thin coating of orange-coloured kermesite or white valentinite. Gold occurs in the ore, being richest in that metal when the percentage of stibnite is high. The ore occurs in a series of lenses, 50 to 60 ft. in diameter, and 6 to 24 in. thick, which pitch about S.E. 45°.

"A deposition of antimony ore is still going on. On the face of a cross-cut driven 100 ft. from the vein a thin layer of sulhpide of antimony was found, a small stream of water

was met, and the smell of sulphuretted hydrogen is quite perceptible. A soft red sulphide is also forming. This may be due to antimony being dissolved from the upper level and redeposited at greater depth " [53/p. 296].

The remaining two veins are only from 4 to 5 in. thick on an average, and have not been mined to any extent. No igneous rocks are to be found near the deposit.

The production from 1884 to 1908, inclusive, was 10,986 tons of ore. The best years were 1905 and 1907 with 4,000 and 3,042 tons respectively. The gold (obtained only since 1905) amounted to 3,764 oz.

The mines were actively exploited by the West Gore Antimony Co. during the war period, and a depth of 850 ft. was reached in the main shaft. The returns of antimony ore in 1915, 1916 and 1917 were 10,872, 14,149 and 10,660 tons respectively. The ore was concentrated at the mines to a 38 to 45% antimony content. In 1916, the 14,149 tons of ore yielded 856 tons of concentrate, containing 603 oz. gold [54].

Ontario.—Antimony ores appear to be of rare occurrence in the Province of Ontario. Stibnite has been met with in small quantities in association with pyrite and mica in the township of Sheffield, Addington Co., and in small masses, mixed with tremolite, under similar conditions, in the township of Marmora, Hastings Co. [55]. In the Queensboro mine, Madoc township, Hastings Co., is a series of lenses of pyrite in decomposed schist close to a granite contact. To the west of the workings is a vein, 2 ft. wide, striking N.W., of quartz, pyrite, chalcopyrite and argentiferous jamesonite. The last mineral fills the interstices, and is formed around crystals of pyrite. It is of later age than the pyrite deposit [56]. Jamesonite has also been found in Barrie township, Frontenac Co., where it is associated with minerals rich in silver [57].

The native silver of Cobalt district usually contains both antimony and mercury. The former is believed to be in the form of dyscrasite (Ag_6Sb). Five specimens analysed gave from 0·17 to 6·59% antimony [58]. Other antimony minerals occurring in the Cobalt district are breithauptite (NiSb), pyrargyrite, stephanite, polybasite, and tetrahedrite. W. H.

Collins [59] records the presence of stibnite in a vein in the Rosie Creek area (Unwin and Browning townships) which also contains chalcopyrite, galena, smaltite and cobalt bloom with silver in traces only. The veins of the area are described as being of good size, but crooked. They occur in dolerite ("diabase") resting on quartzite or upon Laurentian granite.

Quebec.—Antimony ore was discovered in bluish quartz veins at South Ham, Wolfe Co., in 1863. The main vein intersects pre-Cambrian schist or argillite, striking N.E.–S.W. to E.W., and is traceable for ½ mile. At and near the surface the vein is 2 ft. in thickness; at a depth of 100 ft. it is 6 ft. thick. The quartz carries native antimony and less amounts of stibnite, kermesite, senarmontite and valentinite. The stibnite appears as acicular crystals in the quartz, or is concentrated in rich pockets, some of which were 2½ ft. thick. It is said that 180 tons of ore were extracted and shipped from the old workings. A small plant was erected [60]. The vein, which is said to contain 5% stibnite, has been worked intermittently since then.

Dresser [61] describes the deposit as a contact one, occurring, as it does, in schists along their contact with an intrusion of dolerite ("diabase") and serpentine. The principal amount of ore appears to be in flakes along the cleavage planes of the schist. The antimony ore only yields a trace of gold.

A small vein of stibnite occurs at New Richmond, Bonaventure Co. According to Mailhiot [62], the vein is vertical, strikes N. 46° E., has a maximum thickness of 6 in., and consists of stibnite disseminated in a quartz gangue. The vein is on a contact between a conglomerate and quartzite. The vein was prospected by trenching for a length of 110 ft., and by a shaft 40 ft. in depth. The occurrence appears to be of no economic value.

Yukon.—According to Cairnes [63], antimony ores occur in an area 3 to 4 miles long by 2 miles wide, on the Carbon and Chieftain Hills, near the Wheaton River. The ores were discovered in 1893. The deposits occur as fissure veins chiefly in granites and andesites, also in the fragmental rocks of the Laberge Series (Jura-Cretaceous). The veins are from a few inches to 5 ft. wide, and usually strike a few degrees N. of W.,

and dip N. 40° to nearly vertical. The filling is quartz with stibnite, associated, in one locality, with arsenopyrite, or quartz with some barytes and stibnite, blende, tetrahedrite and galena (silver-bearing). There may be antimony ochre at or close to the surface. The stibnite itself is argentiferous in many places. Some of the veins are traceable at surface for 2,000 ft. in length. Some of the surface ore contains a considerable amount of galena and tetrahedrite, and carries 100 to 200 oz. silver per ton. Typical silver-lead-antimony ore from one claim assayed 50 oz. silver per ton; 31% lead, and 18·75% antimony. Cairnes regards the deposits as being unusual developments of rich silver veins. The age of the ores is late Cretaceous or early Tertiary, and they are probably genetically related to the andesites.

In 1915, there was a small shipment of antimony ore from Tagish Lake.

In the Duncan Creek Mining Division, stibnite occurs close to the Stewart River, about 5 miles above Gordon landing. The ore, associated with quartz, is deposited in the fractures of a thrust-fault in the schists [64].

Small quantities of stibnite have been observed distributed in massive garnet (grossularite) which accompanies bornite at the Copper King and Anaconda claims on the White Horse copper-belt, on the west side of Lavis River.

In addition to antimony ores, Canada produced some refined antimony in 1907, 1909, 1915 and 1916. The Consolidated Mining and Smelting Co. at Trail, British Columbia, obtained the greater part of the metal as a by-product in the treatment of the silver-lead ores of that province; the remainder was from New Brunswick ores, treated locally.

Newfoundland

According to Howley [66], a most promising deposit of stibnite was mined for a short time at Morton's Harbour on New World Island, in Notre Dame Bay, Newfoundland. Altogether a few thousand tons of high-grade ore were extracted. In 1890 and 1891 ore to the value of $2,200 was

sent to market [67]. Prior to 1897, about 150 tons of ore had been shipped altogether [68].

Stibnite also occurs in other parts of Notre Dame Bay.

AUSTRALASIA

Australia

New South Wales.—This state has for a good many years been a small, but irregular, producer of antimony. From 1880 to 1921, inclusive, the production of ore and metal amounted to 19,032 tons of value £344,588, an average of about 453 tons per annum. The highest production was in 1906, with 2,450 tons, and the lowest in 1903, with 13 tons. From 1915 to 1918 (war period) the output of ore and metal amounted to 1,911 tons.

The antimony deposits of New South Wales are distributed in a general N.E.–S.W. direction, from Co. Buller in the N.E. corner of the State to Co. Forbes, in the S.W., lying considerably west of Sydney. In the following notes, the chief deposits are described, commencing in the north.

At Lunatic, Co. Buller, 7 miles north of Drake, antimony occurred in an oxidized surface "blow" which carried up to 15 dwt. gold per ton. Antimony quartz reefs strike N.–S., are vertical and traverse slate. A large quantity of antimony ore was raised from here in 1910.

At Pucka, Yulgilbah Station, Co. Drake (Lionsville district), two lodes occur, striking N. 65° E., about 12 ft. apart. One of the lodes varies from a few inches to 18 in. in thickness and carries stibnite and antimony oxide in a quartz gangue [69]. Antimony ore has been discovered in several other places in this county. At Pulgenbar, stibnite, in small quantity, is associated with mercurial ores (*see* Imperial Institute monograph, *Mercury Ores*, 1923, p. 28).

Card records massive native antimony with a crust of oxide, 25 miles north of Armidale, Co. Sandon [70], and near the same place a vein of antimony is said to occur 10 to 15 in. in width.

The principal production of antimony in New South Wales has been from the Hillgrove Division, Co. Sandon. Antimony

ore was discovered at Gara (Hillgrove district) in 1853, but was not mined until 1880.

The formation consists of granite and metamorphosed sedimentary rocks, probably of Devonian age. The Eleanora reef strikes N.W. and dips N.E. 80°. The Cosmopolitan reefs are believed by some to be the northern continuations of the Eleanora, which would make this particular line of reef traceable for 1½ miles. The Eleanora reef consists of dark-blue siliceous slate crossed by a network of quartz veins, which give it a brecciated appearance. A much-altered dyke accompanies the vein, and generally divides it into two. Stibnite and oxide of antimony occur in irregular bands or are finely disseminated through the reefs. The lode may be regarded as a huge low-grade ore deposit. In places its width, with the included dyke, is 22 ft.

Prior to 1891, the mine produced about 578 tons of "crude" and metal. From June 1892 to December 1899, 74,560 tons of ore treated yielded 31,477½ oz. gold, 2,150½ tons of antimony concentrate, 1,980 tons of crude antimony, 85 tons of star antimony and 14½ tons of artificial oxide of antimony. The mine was not working from 1902 to 1905, but in 1906 120 tons of stibnite were raised therefrom.

Garibaldi, which is a S.E. extension of the Eleanora line of reef, has been worked to a depth of 240 ft.

The two Cosmopolitan reefs to the north are in granitite, and have produced many large parcels of antimony ore, one yielding 100 tons of metal.

The Sunlight reef, Metz, to the west, strikes W. 25° N. in crushed and faulted slate and schist, parallel to the outcrop of a granitic intrusion. This is a gold-bearing lode, but magnificent crystals of stibnite are found in vugs. In the western end the workings are 800 ft. in depth. The Black Lode mine, at Metz, in 1918 yielded 216 tons of ore, which were smelted at Sydney [71].

Stibnite is associated with scheelite in small lenses and thin veins in granite in this district [72/p. 24].

At the head of Swamp Creek, two large antimony reefs occur, 60 ft. apart, dipping slightly towards each other. Close on 2,000 tons of antimony have been extracted from these

lines of reef. Brackin's Spur and Beck's Antimony Lode are two other localities from which considerable quantities of antimony have been raised from time to time [73/p. 42].

At Bowra, near Nambucca River, Co. Raleigh, several antimony reefs occur. O'Donnell's reef, 2½ miles north of Bowra, is a well-defined breccia quartz reef 2 to 5 ft. thick, containing stibnite and pyrite. It strikes N. 15° W., and has been tested to a depth of 80 ft. Another antimony-quartz reef strikes N. 20° E. to N.E., and is 3 in. to 3 ft. wide. Several hundred tons of ore have been shipped from the mines at Bowra.

At Mungo Creek, Carangula, Co. Dudley, antimony lodes occur in rocks of Permo-Carboniferous age. The strike is N.–S. to N.E.–S.W. Stibnite, with some cervantite, occurs in irregular bunches in a quartz matrix. A sample of mixed sulphide and oxide gave 2½ dwt. gold, and silver traces, per ton. A small smelting plant was erected here. In 1893, the output of ore from the Kempsey district was estimated at 866 tons, valued at £7,466 10s., and was presumably from Carangula and neighbourhood.

At Nundle, Co. Parry, antimony has been known for about 50 years. The reef strikes N. 20° W., dips N.E. in slate, and is a few inches to 18 in. in thickness. A few tons of ore were shipped from here.

The Razorback antimony lode is in the parish of Walberton, Co. Roxburgh. An auriferous quartz reef, containing pyrite and stibnite, traversing black slate country rock, is accompanied by a dyke. The strike is N.–S., the dip W. 60°, and the thickness 1 to 5 ft. The vein-channel is filled with broken and crushed "country," quartz and calcite. A sample from the 130-ft. level gave 4·1% antimony and 3 dwt. gold per ton. It may be regarded as a gold mine, the antimony being too low in amount to be payable alone. Work was suspended here in 1902. The main shaft exceeded 300 ft. in depth [74/p. 9].

At Crudine Creek, near Sofala, also in Co. Roxburgh, an antimony vein occurs in a line of fault of Silurian slates. It is a breccia lode, striking N.W. and dipping S.W., and is 8 in. to 3 ft. wide. Stibnite and oxide of antimony occur in lenticular patches in the quartz gangue. Some ore has been raised from here.

Near Orange, still farther south, in Co. Wellington, is the Wentworth gold mine, where native antimony, calcite and rich gold occur at the junction of serpentine and diorite. A sample showed the following percentages: Carbonate of lime, 59·20; metallic antimony, 38·75; gold, 0·026; silver, 0·005; oxide of iron, 0·750; silica, 0·350; sulphur, 0·570; magnesia and loss, 0·349 [69/p. 39]. Stibnite and very rich arsenopyrite also occur occasionally in this lode [75/p. 246].

An auriferous antimony vein occurs on the Cudgegong River, also in Co. Wellington, and is reported to be 8 to 12 in. wide, and to have been opened up to a depth of 100 ft.

Native antimony, stibnite and kermesite have been found in the Australian Broken Hill Consols lode, and dyscrasite (pseudomorphous after siderite) and tetrahedrite occurred at all levels, except at very shallow depths. About 10 tons of dycrasite were found in all, the largest individual piece was estimated to weigh 30 cwt. Assays of a number of samples gave 6 to 27% antimony, and 94 to 73% silver [74/p. 5]. In the upper levels the mineral was changed to chloro-antimoniate of silver [76/p. 407]. Jamesonite, in fibrous lumps, was found in the Pinnacles Consols and in the Lady Carrington mine, Apollyon Valley [76/p. 414].

The Broken Hill Proprietary Co. has from time to time produced a quantity of antimonial lead at Port Pirie Smelting Works.

Queensland.—Queensland has been a small and intermittent producer of antimony ore since 1873. The total production from 1873 to the end of 1921 amounted to 4,578½ tons. The two best years were 1884, with 748 tons, and 1906, with 530 tons. In 1915 and 1916, the State produced 192½ and 192¼ tons respectively. Since 1916, the output has amounted to 2¾ tons only (1919) [77/1921, p. 21].

The antimony deposits have been described by B. Dunstan [78].

The Chillagoe mineral field in North Queensland, which lies some 75 miles S.W. of Port Douglas, contains the most extensive antimony-bearing area in the State. The belt is about 30 miles in length, and consists of shales, slates and sandstones. Gold and silver usually occur with the antimony, and in the

past, some of the lodes have been worked principally, if not exclusively, for gold. At Northcote, which lies about 44 miles W.N.W. of Chillagoe, stibnite occurs in a quartz gangue with cervantite, pyrite and gold [79]. The Violet lode appears to be a crushed zone in sandstone and quartzite (Carboniferous). The strike is E.-W., and the dip S. at a steep angle. An average sample of the lode formation taken over a width of 6 ft. yielded Saint-Smith: Antimony, 15·7%; gold, 11 dwt. and silver, 11 dwt. per ton of ore. A sample of stibnite from the New Minnie Moxham gold mine yielded: Antimony, 41·6%; gold, 4 dwt., and silver, 4 dwt., per ton of ore [80]. The stibnite occurs as seams from a few inches up to 2 ft. in length, frequently carrying paint gold. Much of the stibnite is exceedingly fine-grained. Well-developed crystals of barytes occur at times through the upper portion of the lode. The gold content is said to increase with that of the antimony [81].

Antimony lodes also occur at Woodville, Mt. Mulligan, 32 miles N.E. of Chillagoe. A crushing and concentrating plant for the treatment of low-grade ore was erected here. At Mitchell River, 40 miles N. of Chillagoe, the principal lode strikes N.N.W., is nearly vertical, and 5ft. and upwards in width. It is a replacement bed in slate "country" of the Hodgkinson Series (Devonian). The lode is traceable for ½ mile. The antimony ore carries a little gold and silver [82]. Smelting works were erected at Mitchell River for treating the local ores, as well as those of Northcote, etc. Liquated crude, regulus and white oxide were produced from these ores and exported to England.

At Cocoa Creek, 33 miles N.N.W of Cooktown, in North Queensland, is a series of veinlets in slates, quartzites and sandstone. The quartz gangue carries stibnite, cervantite and gold. A gold-antimony lode, discovered here in 1890, strikes E. 30° S., dips S. 85°, and averages 1 ft. in thickness, with bunches up to 4 ft. [83]. The "country" is described as schist and slate. Both antimony and gold were found to decrease in depth. In 1921 an antimony lode was discovered near Cooktown [77/1921, p. 14].

At Hungry Hill, near Eidsvold, 100 miles west of Hervey Bay, a large quartz lode is exposed for over a mile in length,

containing antimony ore in numerous places, freely mixed with the quartz gangue. The "country" is decomposed micaceous granite close to altered slates. A sample of ore from the lode gave upwards of 60% antimony and a little gold and silver [79/p. 919]. This and other antimony lodes in the district have been opened up to a certain extent by shafts and levels.

At Neerdie, 14 miles N. by E. of Gympie, which is about 100 miles north of Brisbane, the lodes are made up of quartz veinlets and brecciated shale formation in sedimentary rocks close to granite. Small quantities of gold and silver and some cervantite occur with the stibnite. Ore was first exported from these mines, then crude antimony. The lodes have been worked intermittently since.

West of Tiaro, 35 miles north of Gympie, is an antimony lode several feet wide in "country" consisting of shales, sandstones and limestones. The ore is stibnite and cervantite without any gold, although a mineralized gold-bearing quartz lode exists quite close to the deposit. The lode has been explored at surface only.

The Chatsworth antimony lode, close to Gympie, is in the limestone belt forming the upper portion of the Middle Gympie (gold-bearing) Series. Stibnite and cervantite occur irregularly in this lode, without, it is said, any quartz.

In 1917 all antimony mining practically ceased in the State, owing to the low market price of the metal.

Victoria.—Antimony-quartz veins are found in Victoria traversing rocks of both Silurian and Ordovician age. All the principal occurrences are within a radius of 50 or 60 miles of Bendigo.

The auriferous antimony veins of Costerfield, at Heathcote, about 20 miles S.E. of Bendigo, are the most important. Here stibnite and antimony oxides occur in quartz veins cutting Ordovician slates. The deposits were discovered about 1860, and have been mined for a long time. A company worked the oxidized ores for some years, leaving 60,000 tons of tailing assaying 6% antimony and 7 dwt. gold per ton. A new company is now treating the sulphide ore and tailing successfully. The main shaft is 1,000 ft. in depth. The milling ore

averages 8% antimony and 10 dwt. gold per ton. The fine concentrate is treated by the minerals separation (oil flotation) process [84].

In 1919, 4,322 tons of ore yielded 1,208 tons of concentrate, averaging 50% antimony, and 2½ oz. gold per ton, of value £24,160. In 1920, 4,678 tons of ore gave 961 tons of concentrate, containing on an average 52% antimony and 2¾ oz. gold per ton, of value £14,238 [85/1920]. There are now smelting and refining furnaces on the mine. In 1923, the oxidizing unit produced 64¼ tons of oxide from 104¼ tons of ore and concentrate. The oxide is being utilized for the production of Antox paint [86].

An auriferous antimony lode cuts Silurian mudstones, sandy shales and sandstones at Tyaak, Broadford, in Co. Dalhousie, 55 miles S.E. of Bendigo. The crushed beds of sandstones and shales contain antimony oxide in lenticular patches and on the joint planes. In addition, there is a lode here, striking W. 20° N., dipping N. 70°–50°, from 6 in. to 2 ft. in width (averaging 14 in.), containing stibnite, with some oxide, principally confined to a band from 4 to 6 in. in width on the foot-wall side. An average sample from the bottom level gave: Antimony, 2·27%; gold, 6 dwt. per ton, whilst the material from the foot-wall yielded: Antimony, 8·64%; gold, 9 dwt. and silver 2 dwt. per ton [87] [88].

At Whroo, Co. Rodney, about 50 miles E.N.E. of Bendigo, very remarkable concretions are found in the veins consisting of concentric layers of differently coloured oxides surrounding a central nucleus of stibnite. All through the oxidized portions gold is disseminated in the form of ragged grains, varying in size from a mere speck to pieces as big as a pea.

A stibnite vein occurs at Munster Gully, Dunolly, Co. Gladstone, 20 miles W. of Bendigo, and at Donovan's Creek, on the Upper Yarra, a lode, from 6 in. to 2 ft. in width, consists almost entirely of bright and nearly pure stibnite.

At Sunbury, Co. Bourke, 50 miles S.S.E. of Bendigo, a vein of quartz and stibnite has an irregular course in Silurian strata. It sometimes appears as a bedded vein, and sometimes crosses the strata obliquely. It carries 2 oz. gold per ton [89/pp. 647–8].

Lenticular patches of stibnite occurred in McFarlane's Reef, Maryborough goldfield, Co. Talbot, S.W. of Bendigo [90].

Jamesonite is found in small quantities in the lodes of Wood's Point goldfield, Wonnangatta, about 120 miles S.E. of Bendigo [91].

Western Australia.—Very little antimony ore has been produced in Western Australia. The first recorded output was in 1903, when 22 tons, valued at £230, were exported from the State. The whole quantity exported up to the end of 1929 amounted to 88½ tons, valued at £1,743.

The antimony deposits of Western Australia have been described by A. Gibb Maitland [92].

In the West Pilbara goldfield, an antimony-quartz lode in greenstone, near the Sherlock River, has been explored to shallow depths. The stibnite is either disseminated through the quartz, and is then very rich in gold, or is in pure solid lumps with some cervantite. Near Mallina are several antimony-quartz veins. One of these, striking N. 10° W. and dipping N. 70°, from 6 to 8 ft. wide, has been proved to shallow depths. The country rocks are highly plicated schists and sandstone. The antimony ores (stibnite, cervantite, and a little valentinite) occur in bunches. The 1903 shipment was from this vein. Small antimony veins, containing gold, occur 5 miles east of Mallina, near the Peeawah River. Near the surface they carry high gold contents. One was proved to a depth of 47 ft. in calcareous slate, but at this depth, the stibnite, although of good quality, was practically destitute of gold. About 20 tons of ore have been shipped from here. Some ore has also been raised from Balla Balla.

In the East Murchison goldfield, some of the auriferous quartz reefs of Wiluna have been found to carry stibnite. The country rock consists of fine-grained hornblende rocks, approaching quartz-diorite in composition. The greenstone is traversed by well-defined narrow belts of schists, which represent crush zones or shear lines, and it is along these belts that the main line of reefs and lodes occur. The reefs may be from 3 to 5 ft. in width. The stibnite is apt to occur in lenticular patches or masses, containing up to 1 ton or more of the ore, which usually contains some silver and gold. Near

the surface cervantite and stibiconite are found. Some of the lodes have been mined to a small extent. One quartz reef, associated with the wide lode of the Gwalia Consolidated strikes N.N.E., and carries some stibnite and stibiconite.

In the normal quartz reefs of Western Australia, which occur in amphibolite or along the contact of granitic rocks and amphibolite, galena, blende, arsenopyrite, stibnite, bismuthinite and other minerals accompany the native gold [145/p. 690].

Tasmania.—Stibnite occurs at Tasmania in Mt. Bischoff, Mt. Zeehan, Heazlewood River and Table Cape. In the last locality it occurs with galena [93].

New Zealand

New Zealand has been a small and intermittent producer of antimony ore since 1878. From that year to 1921, the total production amounted to 3,781 tons, of value £55,045. The best period was from 1885 to 1893, when the output amounted to 3,355 tons, or an average of 372¾ tons per annum. The two best years were 1885, with 666 tons, and 1890, with 515 tons [94].

Most of the antimony ore raised in the Dominion has been from a deposit at Endeavour Inlet, Queen Charlotte Sound, Marlborough Province, in the north of South Island. The reef, which was discovered in 1872 or 1873, was officially reported on by S. Herbert Cox a few years later [95]. The lode strikes N. 55° W. to S. 55° E., and dips N.N.E. 50°, in what is described as a fine-grained greenish schistose rock. The lode is traceable for about 4 miles, and the proved width is 3 to 4 ft. The ore is stibnite with quartz gangue disseminated through it, the sulphide being coated with stibiconite and kermesite. With the antimony are found loose blocks of olivine with chromium ore, compact hornblende rock and white and green chert [96]. The lode had been worked near the top of the range (altitude 1,600 ft.). By 1887, it had been proved for a length of 1,000 ft., and about 3,000 tons of ore had been raised, some of which was shipped direct to England. The upper portion of the deposit was found to be valentinite. The stibnite continued to be rich in a drive 175 ft. below the adit, or 450 ft. below the crown of the range. The best ore was

hand-picked; the poorer ore was crushed and dressed by jiggers, etc. The ore was liquated first in crucibles, then in a reverberatory furnace. The "crude" was converted into regulus (or metal) which was refined to star antimony, at the smelting works on the mine [97] [98].

About 600 ft. from the main lode is a parallel one with a similar dip, up to 12 in. thick, consisting of stibnite scattered in small pieces in a quartzose gangue. A third lode has a course perpendicular to the other two, and dipping W.N.W. 30° [95]. Production from this mine practically ceased in 1893.

A well-defined antimony lode was discovered at Stony Creek, Waipori, Otago, South Island, in 1870. In 1875, 60 tons of antimony ore was raised from here and shipped to England [97]. The lode, which is composed partly of fibrous and partly of compact stibnite, is 2½ ft. in thickness, and has been traced for several hundred feet [96]. An antimony lode has been worked from time to time at Hindon, Waipori. After various vicissitudes, in 1891 a lode, 2 to 5 ft. thick, was struck at a depth of 60 ft., and yielded from 70 to 80% antimony. The company working the mine carried on continuous operations during 1892. The yield of ore down to 1892 amounted to 500 tons.

Antimony ore was found on the Carrick Range, near Cromwell, Otago (altitude 3,000 ft.), a few years prior to 1887, and an unsuccessful attempt was made to develop the deposit, which consisted of thin veins, traceable for upwards of a mile in grey foliated mica-schists [96].

An antimony lode, at Alexandra, on the West bank of the Molyneux River, Otago, was reopened in 1901–2, and again in 1906, but without success.

Antimony also occurs at Mt. Stoker, Otago, and on Kawau Island, Hauraki Gulf, South Island, an antimony lode was found 1 to 5 ft. in width. Antimony ores are found in some of the auriferous lodes in the Thames and Coromandel districts of North Island; at Reefton, and Black's Point, 1½ miles from the Inangahara River (altitude, 1,400 ft.), and at Langdon's reef, near Greymouth, in South Island.

In the Thames district, stibnite occurs as fine crystals in druses [99]. One quartz reef, near Greymouth, was in hard

blue cherty slate, and had the following section, starting from the foot-wall side: Quartz, 2 ft. in thickness, with stibnite dispersed in irregular masses; compact stibnite, 2 ft.; stibnite, including quartz in the form of nodules, 3 ft.; fine-grained mixture of quartz and stibnite, 4 in.; slate breccia, 1 ft. 8 in. The first samples taken of the antimony ore proved highly auriferous, but subsequent explorations were unsatisfactory [96].

An antimony lode, containing massive stibnite, cervantite, senarmontite and kermesite occurs at Waikari, Bay of Islands, North Island.

In 1907 a deposit at Russells, about 6 miles from Opua, Bay of Islands, was opened up and about 50 tons of ore were shipped [28/p. 407] [100/p. 399].

CHAPTER III

SOURCES OF SUPPLY OF ANTIMONY ORES (*continued*)

(*b*) FOREIGN COUNTRIES

EUROPE

AUSTRIA

AT Rohoncz (Rechnitz), antimony veins occur in crystalline schists, and are especially rich where the country rock is chloritic or graphitic. The filling consists of quartz, calcite, stibnite, stibiconite and pyrite. The solid antimony ore is from less than 1 to 20 in. in thickness, but the country rock (graphitic schist) for a width of 10 to 13 ft. is richly besprinkled with stibnite, together with pyrite (slightly auriferous) and cinnabar, and is mined with the rest of the vein [101].

CZECHOSLOVAKIA

At Pricov, near Selcan, Central Bohemia, a number of kersantite dykes, occurring in granite, are accompanied by veins of hornstone rich in stibnite. Antimony ore was raised for many years, but the workings were abandoned in 1897. Stibiconite was found to a depth of 59 ft. The largest vein was 65½ ft. in width, but stibnite occurred in the vein only with hornstone of a light grey colour. The only lode worked was 2 to 20 in. wide [101/p. 336]. The filling consisted of milk-white or bluish hornstone with crystals of stibnite regularly scattered in radial aggregates throughout. The hornstone was found in places to have been recrystallized and transformed into ordinary quartz. The antimony ore was non-auriferous.

In the neighbouring districts of Schönberg and Mileschau,

auriferous quartz-stibnite lodes occur in granite traversed by kersantite dykes. The gold-content varied between 2½ and 11 dwt. per ton.

Near Kritz, in the neighbourhood of Rakonitz, an antimony lode occurs at the contact of phyllite and dolerite (" diabase ") [102/p. 780].

At Punnau, near Marienbad, antimony lodes occur in mica-schist and amphibolite near the great granite massif of that locality [101/p. 336].

Antimony ores are associated with gold in the Joachimsthal district, and jamesonite, boulangerite and other antimony minerals are found in the silver-bearing lodes of Pribram.

This is notably the case in the lower levels of the Anna shaft (depth 1,896 ft. in 1857), in which quartzose ores carry a little calcite and some stephanite, miargyrite, native silver, tetrahedrite and stibnite [31/**3**, p. 121].

In 1912, Bohemia produced antimony to the value of 1,000 kronen.

In Slovakia, gold and antimony ores are mined in several parts of the counties of Zólyom and Liptó, and antimony ore alone in the counties of Pozsony and Liptó. In 1913 Slovakia produced 6,217 metric tons of antimony ore. The chief mines were at Rozsnyo, the output being 1,547 tons. There are antimony works at Fejerko [103].

The auriferous antimony lodes of the mining village of Magurka, which lies at an altitude of 2,500 ft., were described long ago by Von Cotta [104] [105/p. 300] [106]. The rock of the region is a normal granite, but, alongside the most northerly lode, the only one worked, it has been considerably altered, and contains some pyrite and antimony ore. The vein, which is split up into five parts by faults, is from a few inches to several feet in width. The filling consists of stibnite (usually in the centre) and quartz and " horses " of granite, as well as finely divided argentiferous gold and some pyrite, yellow blende, chalcopyrite, dolomite, calcite, and fine threads of argentiferous galena—the last chiefly in the country rock. The stibnite was over 6 ft. wide at one point—elsewhere the ore and country rock are mixed, or the fissure becomes narrower.

Sometimes the quartz is separated from the granite by a band of younger dolomite.

Veins of stibnite, with a gangue of quartz and carbonates, and small amounts of jamesonite, berthierite, blende and auriferous pyrite were at one time worked between Aranyidka and Rosenau [101/p. 336].

Antimony ores are associated with gold and silver in Ruthenia [107].

France

Before the war France was the largest producer of antimony ore in Europe. From 1912 to 1918 the annual production averaged about 13,000 metric tons of ore, or about 2,600 tons of metal. Since 1918 there has been a considerable drop in production, as will be seen by reference to the table on page 24.

At La Lucette (Mayenne), stibnite occurs in nearly vertical quartzose veins traversing quartzites and schists of Upper Silurian age [31/1, p. 761]. As a rule the veins, which strike N.N.E.-S.S.W., are of moderate width, and mostly without continuity. The *filon Georges*, discovered in June, 1900, appears to be the master lode of the district. It has been described by Bellanger [108], and was worked from 1900 to 1913 for a length of 656 ft. and to a depth of 1,115 ft., with a gross production of 443,402 tons of ore, which yielded 175,000 to 180,000 tons of metal containing 40% antimony and about 180,000 oz. gold. The average thickness of the deposit mined was nearly 10 ft. The lode occurs in quartzite, or between quartzite and schist, the latter generally forming the foot-wall. It often assumes a roughly banded structure, bands of stibnite being separated by bands of quartz. The quartzose gangue frequently encloses large angular fragments of schist and micaceous quartzite. Some calcite is also present, and, in order of frequency, stibnite, arsenopyrite, pyrite, blende and free gold. Traces of platinum, nickel, cobalt, copper, lead and tin have been found in the lode according to H. Douxami [108]. There was an increase of free gold to a certain depth, when nuggets were found weighing from 6¼ to 32 oz. According to Pautrat [108], the gold does not come from the stibnite.

but simply from the quartz more or less charged with arsenopyrite and pyrite which accompanies it. As a matter of fact, stibnite did not go below 980 ft. in vertical depth, although gold in unpayable quantities was still found in the bottom levels. The age of the deposits is considered to be Devonian. The *filon Georges* and some mines in the district of Rochetrejoux (Vendée) have long been the chief producers of antimony ore in France.

At Semmon (Ille-et-Vilaine) a lode, about 23 ft. wide, traverses Archæan schists at a diorite contact. The filling is quartz, containing veinlets of stibnite in the centre up to 2 or 3 in. thick, with some calcite. It also contains a little pyrite (slightly auriferous), tetrahedrite and chalcopyrite [31/**1**, p. 750].

The Central Plateau comprises a great many antimony veins, most of which have been mined at different times.

At Bresnay (Souvigny) two antimony-quartz veins occur in granite. Farther south, antimony deposits abound around an intrusion of microgranulite. At the Nades mine (Bourbon), two quartzose veins are in mica-schist. At Montignat (Allier) is a stockwork of stibnite and quartz in a dyke of rock, intermediate between granulite and microgranulite, which penetrates a very granitic gneiss. The antimonial veins are very irregularly distributed in the dyke. The stibnite is associated with quartz, a little calcite and arsenopyrite, forming veinlets, which are ¼ to ¾ in. thick, whilst, here and there, lenses of stibnite occur. At Mérinchal (Creuse) stibnite is localized in a granulite passing into microgranulite. At Chanac (Corrèze) a stibnite vein, 1¼ to 2¼ in. width, is intercalated in blackish argillaceous schist. The stibnite contains a little iron, but no arsenic, lead or silver [109].

The important deposits of the Central Plateau are those mined at Massiac, Brioude, etc. (Cantal, Haute-Loire). These deposits are in Archæan gneiss, mica-schist or granite. They are in vertical veins containing lenses of stibnite separated by sterile intervals—for example, a vein of compact sulphide, from 8 to 12 in. thick, and 40 ft. in length, is followed by 30 to 50 ft. of more or less sterile ground. Sometimes the sulphide is intimately mixed with the quartzose gangue.

The stibnite is nearly always accompanied by pyrite and arsenopyrite—the last occasionally auriferous. Galena is frequently present. Oxides of antimony are found at the outcrops.

The antimony lodes of Freycenet (Haute-Loire) have been described by Burthe [110]. They strike N.–S. or E.–W. in mica-schist (principally) and gneiss. The stibnite occurs in bunches, rarely exceeding a few cubic yards in size, separated by barren filling. In the poorer portions of the lode, the filling consists of schist, or of compact bluish quartz besprinkled with fine needles of stibnite. Pyrite is somewhat scarce. Some calcite is present and there are traces of blende, but lead, arsenic, gold and silver are absent. In lode No. 1, which runs E.–W., the bunches of stibnite are separated by 15 to 20 ft. in length of sterile matter, the whole forming a column about 200 ft. in length and 165 ft. in height. The hanging-wall frequently contains veinlets of stibnite. In lode No. 2, also striking E.–W., a column of ore was worked for a length of 207 ft. and a height of 321 ft. These two lodes from June, 1889, to December, 1890, produced about 648 metric tons of ore which realized 148,060 francs. More than half this ore was low in grade.

Besides the above there are in the same district complex lodes containing quartz and highly argentiferous antimonial galena with a little barytes.

A little farther north are the less important deposits of Mercœur, Valadau and La Licoulne (Haute-Loire). The lodes are in a plateau of gneissic rocks (altitude 3,040 ft.) The Bissade lode of Mercœur has an average direction of N. 26° E, and can be traced for 1½ miles in length. The filling is massive stibnite with a little quartz. The ore is 1 to 1½ ft. wide, sometimes for a length of 164 ft. Occasionally the lode splits into many branches; generally it forms big lenses terminating in veins which replace one another. The ore contains traces of silver. The Valadou lode strikes N. 54° E. in Archæan schists. The ore is in a series of columns, up to 12 in. in thickness, but separated by absolutely barren parts; it is rather more argentiferous than that of Mercœur. The lode is cut by a quartzose vein, striking N. 30° E. and spotted with stibnite. The two most important veins of La Licoulne

group have been explored for an altitude of about 1,000 ft. The mineralization is less than that at Bissade.

At Malbosc (Ardèche) are quartzose lodes, coursing N.W.–S.E. in mica-schists resting on granite. The lodes contain a little calcite and barytes. Stibnite, disseminated in the veins, is in radiated patches or in very irregular veins 4 to 8 in. thick. The stibnite may be on either wall, or it may be split up or disappear entirely. Exploitation for this reason ceased long ago. At Charmes, Triassic dolomite, resting on granite, is impregnated with silica and stibnite. The dolomite is in irregular masses and consists of brown silica accompanied by barytes and stibnite, sometimes forming veins, and sometimes in radiated nodules. A later metallization has here formed a sort of bedded vein. The age of the deposit is post-Triassic and may be Tertiary [31/**1**, p. 755].

The antimony deposits of Algeria, which for statistical purposes is considered a part of France, are described on page 77.

Three antimony mines in Corsica have been described by Nentien [111]. The lodes occur in sericitic schists, with which are intercalated some calc-schists, said to be of Archæan age. Some antimony-bearing cross-veins occur in Meria, but their continuity is less than those running E.–W. The veins are steeply inclined, and the gangue is quartzose. At San Martino one vein in altered argillaceous schist is filled with stibnite enclosing kernels of milky white quartz and fragments of a green rock surrounded by calcite. There are spots of blende near one wall, which is separated from the vein by a band of calcite. The best ore is generally on the foot-wall, which is well defined, with slickensides. The ore is in columns or shoots (*trombes* of the Corsican miners). The filling is stibnite with a little pyrite and isolated spots of blende, cinnabar and bournonite.

At Luri Castello, an antimony lode was explored for a length of about 1,000 ft. and a depth of 410 ft. In fifteen years this mine produced 4,135 metric tons of ore.

The Vallone lode of the Meria mine was proved for a length

of 2,296 ft. There were three or four rich shoots, and from 1880 to 1894 the production amounted to 8,020 metric tons of ore.

The Ersa mine in eight years produced 1,960 metric tons.

At Metra, a lode in serpentine, sometimes brecciated and sometimes banded, carries, besides stibnite, masses of the arsenic minerals realgar and orpiment in calcite and dolomite. The vein has been worked for arsenic [31/1, p. 769].

GERMANY

At Mobendorf, Saxony, stibnite veins with a steep dip occur in gneiss, and rarely exceed 2 in. in thickness. Besides stibnite, they contain some berthierite, bournonite, striated kaolin, antimonial galena, zincite, kermesite, stibiconite, pyrite, quartz and dolomite. Silver is associated with the antimony ore, and mining was carried on here at about 1860. At Bräunsdorf, similar ore is intimately associated with silver in the rich silver quartz veins [101/p. 339]. Near Wolfsberg, in the Eastern Hartz, a lode about 3½ ft. in width occurs in Silurian rocks, consisting of quartz, with some calcite, stibnite, chalcostibite (or wolfsbergite), zinkenite, bournonite, and jamesonite, including the tinder-ore variety. The gangue consists of strontianite, calcite, barytes, selenite and fluorspar [102/p. 779] [105/p. 149].

At the Hoffnung mine, near Brück, on the Ahr, the Devonian slates strike N.–S. and dip W. 45°. The antimony-bearing veins are 6 in. wide, strike E.N.E. and dip S. 40°–50°, forming a shear-zone, from 80 to 120 ft. broad, which had been opened up for a length of 560 ft. in 1827. The ores consist of stibnite with some pyrite. The gangue consists of quartz and dolomite. Besides the veins, there are impregnations of these ores on the bedding-planes and joints [102/p. 1188] [105/p. 195].

In Westphalia, bedded antimonial deposits occur at the Caspari mine, near Uentrop, in the Arnsberg field. Here five ore-bearing beds occur mainly in the S.E. leg of an anticline in limestone of the Culm (Lower Carboniferous) formation. The stibnite is irregularly distributed in these beds in nest-like segregations from 1 to 5 in. thick. The ore also forms sheets

and rods or is finely disseminated in the rock, which occasionally contains a little pyrite, blende, calcite and fluorspar. Similar conditions prevail in the N.W. leg of the anticline, but the ores there are less pure, and consist mainly of stibiconite [101/p. 520]. Krusch believes that the deposit is a metasomatic one [102/p. 784].

A somewhat similar bedded deposit occurs in the Passauf mine, near Nuttlar, in a series of barren sandstones (Culm—Lower Carboniferous) forming the S.W. flank of the Wiemertberg. There are three ore-bearing beds here, the bulk of which is made up of black shales and chert, with bunches of stibnite [101/p. 520] [102/p. 1188] [105/p. 194].

At Böhmsdorf and Wolfsgalgen, near Schleiz, Reuss, S.W. Germany, quartz-stibnite veins occur in Palæozoic schists, together with blende, jamesonite, pyrophyllite and siderite. Some of the veins were extensively mined in the middle of the nineteenth century [101/p. 336].

At Goldkronach, in the Fichtelgebirge, thin auriferous lodes occur in pre-Cambrian clay-slate, which carry some stibnite, especially in the wider portions of the lodes, either in crystalline masses or in fine geodes in needle form, frequently having a radiated structure. Rare minerals are kermesite, jamesonite (?), valentinite and native antimony [105/p. 135].

Greece

Undeveloped deposits of antimony ore occur in the islands of Mytilene and Chios, formerly belonging to Turkey and now in Greek ownership [112/p. 55]. In the former island stibnite-quartz veins occur interstratified in mica-schists [31/**1**, p. 758], but they appear to be of no economic importance.

Italy

Antimony ore has been mined in Italy for a considerable period, nine-tenths of the production, prior to 1915, having come from Sardinia. During the war some mines in Tuscany and elsewhere were worked, in addition to those in Sardinia.

The Pereta mine, S.W. of Monte Amiata, in the south of Tuscany, is a mass of crushed chalcedonic quartz of ellipsoidal

form, intercalated in Eocene calcareous shales in the north, and cutting Miocene limestone in the south. Stibnite occurs as stringers and pockets in the quartz, which is sometimes encrusted with stibnite, or it may enclose small crystals and aggregates of sulphur. The enclosing rocks have been metamorphosed, and have been impregnated with sulphurous emanations which have transformed the *alberese* (a variety of Eocene calcareous rock) in part to gypsum and anhydrite, Hydrogen sulphide (*putizze*) has been detected to the north of the outcrop.

At Selvena, to the east of Pereta and due south of Monte Amiata, stibnite with cinnabar, realgar and pyrite is found in beds of black bituminous clay intercalated in Lias limestone.

At San Martino, south of Selvena, stibnite is in spots, accompanied by calcite and fluorspar, in a mass of crystalline limestone, which is separated from the Eocene beds by a thin cinnabar-bearing selvage.

At Percia Fiorentina, stibnite in radiated kidneys is accompanied by native sulphur and cinnabar in the Eocene limestone.

At Montauto, in the Tafone Valley, concretions of quartz with tufts of stibnite occur at the contact of Eocene limestone and Permian rocks. It is also described as occurring here in great blocks distributed in a black clay containing no other rock except occasional masses of dolomite impregnated with stibnite [3/p. 52] [31/**1**, p. 769].

At the Cetine di Cotorniano mine, west of Siena and north of Monte Amiata, there is a bedded deposit of chalcedonic quartz intermixed with stibnite, at the contact of Permian schists with Rhætic (Upper Triassic) limestone. There are with the quartz some calcite and traces of realgar. Gypsum is present (secondary). There are numerous fissures in the deposit running N.–S., and containing kermesite and valentinite. It is probable that waters charged with silica and with antimony acted upon the limestone, forming the deposit metasomatically. The outcrop has been followed for 1,000 ft. along the E.–W. strike; the deposit dips N. 12° and averages about 40 ft. in thickness. The stibnite is very irregularly disseminated, and the ore treated contains on an average about 5% antimony [31/**1**, p. 768] [89/p. 477]. The deposit may be

compared to that of Kostainik, in Serbia, and Allchar in Macedonia (*see* pp. 65 and 68).

At Pari, near Siena, concretions of quartz with kernels and irregular veinlets of stibnite are found in clays and micaceous schists at the contact of Permian and Eocene rocks.

At Su Suergiu, Villasalto, Iglesias district, Sardinia, the antimony deposits occur at the contact of the Rhætic (Upper Triassic) limestone with Permian slate. Stibnite with pyrite also occurs in mica-schist [3/p. 53]. Scheelite occurs in economic quantities in the lower portions of the Villasalto deposits.

In the valley of Soana di Campiglia, near Ivrea, Torino district (Piedmont), sulphide deposits occur carrying lead, antimony, etc. Jamesonite and tetrahedrite rich in silver are included among the antimony ores [114/p. 23].

In 1921, the Su Suergi and Martalai mines of Villasalto, and the Corti Rosas mine of Ballao, were worked only during the first four months of the year [113/p. 166].

From 1897 to 1914, inclusive, Italy produced 9,667 metric tons of antimony metal, or an average annual production of 537 tons. The best years were from 1901 to 1903, with 1,174, 1,721, and 1,574 tons, respectively. There was no production from 1910 to 1912, inclusive [6/1902, p. 41] [6/1915, p. 36].

The production of antimony ores, and of antimony (regulus, sulphide and oxide) from 1915 to 1921, inclusive, is given in the following tables:

Production of Antimony Ores in Italy [1]

(Metric tons)

Mineral Districts.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
llamissetti .	—	35	78	26	—	—	—	—	—
enze (Florence)	137	1,789	2,105	1,442	—	219	181	—	—
esias . .	4,197	4,685	3,606	1,856	25	663	265	607	1,689
rino . .	—	—	—	45	—	—	—	—	—
Total . .	4,334	6,509	5,789	3,369	25	882	446	607	1,689

[1] *Revista del Servizio Minerario*, 1921 to 1923.

Production of Antimony (regulus, liquated sulphide, oxide) in Italy[1]

(Metric tons)

	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
Firenze (Florence)	66	245	164	110	—	—	—	—	—
Iglesias . .	482	415	371	257	10	80	28	209	295
Total . .	548	660	535	367	10[2]	80[3]	28	209	295

[1] *Revista del Servizio Minerario*, 1921 to 1923.
[2] In addition 80 tons of ground stibnite.
[3] In addition 22 tons of ground stibnite.

PORTUGAL

Portugal for many years has been a small but intermittent producer of antimony.

In the Basin of the Douro, to the east of Oporto, an antimony zone occurs along a Carboniferous-Silurian syncline, trending N.W.–S.E. for about 12½ miles, or, from S. Lourenço d'Armes, in the north, to Gondarem, in the south. Some of the deposits are bedded veins, for they strike N. 10°–20° W. with the country rock (Silurian). Another system crosses them more or less obliquely with a course from N. 30°–60° E. The antimony ores are in several places of the massive type and are slightly auriferous [3/p. 54] [31/1, p. 748]. At Ribeiro da Egrego (Minho), 12½ miles from Oporto, an antimony vein in Silurian schist is 8 to 14 in. in width and carries 1¼ dwt. gold per ton. It was worked unsuccessfully in 1907 [31/1, p. 748].

Antimony deposits also occur farther east at Braganza (Tras Os Montes).

Farther south, at Prata, in the Evora region (Estremadura) is a deposit consisting of a network of fissures at the contact of a granulite dyke, and granite, in the form of a truncated cone. The filling is made up of quartz and stibnite, and the thickness varies from 2 to 8 in.

Still farther south, near the town of Alcoutim, in the district of Faro, on the Huelva boundary, one antimony lode runs

E.–W. and another N.W.–S.E. with the country rock or slate of the Culm formation (Lower Carboniferous) [3/p. 54].

As mined, the Portuguese antimony ore, which is shipped to England, is divided into four classes, containing respectively, 65, 54, 45 and from 30 to 45% antimony sulphide. Even in the leanest grade of ores, as shipped, the gold content is not less than 3 to 6 dwt. per ton, and that of the silver not less than about 1 oz. per ton [6/1906, p. 37].

In 1912 and 1913, Portugal produced 100 and 19 tons respectively of antimony ore. Exports of ore from Portugal in 1916 are said to have exceeded 4,000 tons [17/1919, p. 304].

Russia (including Siberia)

Antimony and argentiferous lead-antimony deposits occur in the Ural Mts., and were stated to be under development in 1912.

Antimony deposits are reported in the Amur Province and in many localities in Siberia [112].

Spain

Spain, like Portugal, has been a small and intermittent producer of antimony ore for many years.

Deposits of antimony ore are known in many localities. For the most part the ore-bodies are irregular and have been repeatedly worked and abandoned.

In the north, much stibnite ore has been mined in the Ribas Valley, in the Catalan Pyrenees. The deposits occur in a belt of metamorphic schists and shales, which are traversed by veinlets of quartz, carrying stibnite. Their strike varies between E. 10° N. and N.E., the dips are varied but generally steep. The shale itself runs N.E.–S.W., stands almost vertical, and for a breadth of about 3 ft. seems to be mineralized by veinlets of quartz with stibnite, and by pockets and impregnations of the latter mineral, the walls of the veins being nowhere well defined [89/p. 505].

Other localities in Northern Spain in which antimony ores

occur are Caurel (Lugo) and the provinces of Orense, Oviedo and León.

The antimonial system of South Portugal is prolonged from Alemtejo into Estremadura, Spain, under the form of thin veins [31/1, p. 749]. In 1892, mines in the region of Zalamea de la Serena, Badajoz, were shipping 500 to 600 tons of antimony ore yearly [6/1892]. Much antimony ore was at one time shipped from the Province of Huelva.

Farther south, near Vinuela, in Malaga, native antimony impregnates the clayey shales, being in crystalline masses from about the size of an egg down to minute metallic spangles [89/p. 505].

From 1915 to 1918, inclusive, Spain produced 1,375 long tons of antimony ore. There appears to have been no production in 1913, 1914, and none since 1918.

SWEDEN

In the Sala mine, in Westmannland, Sweden, stibnite with a little native antimony is associated with highly argentiferous lead ores in veins, which cut the primitive limestone.

At Gladhammar, near Westervik, boulangerite is found in cobalt and copper veins [31/1, p. 765]. (*See* Imperial Institute monograph, *Cobalt Ores*, 1924, p. 41.)

SWITZERLAND

At Lessnig (Eastern Alps), Switzerland, are three antimony lodes 3½ to 6½ ft. thick. Sometimes the richness in antimony increases towards the centre of the lode [31/1, p. 757].

YUGO-SLAVIA

The most important antimony deposits of Yugo-Slavia are in the Kostainik-Krupanj district of Serbia. They have been studied and described by Beck and Von Fircks [101] [115].

The antimony zone runs N.W.–S.E., and is about 9½ miles long and 1 mile wide. Here limestones (probably Triassic) are overlain conformably by slates. There are intrusions of biotite-trachytes and hornblende-andesites in the form of dykes, sheets and stocks, and also, perhaps, as effusive lava flows. The

antimony deposits are intimately connected with the igneous rocks. The principal deposits are interbedded ore masses, underlain by limestone and overlain by slates, but the ore-bearing quartz-mass sometimes extends into the underlying limestones with very irregular borders, indicating that the calcium carbonate has been replaced by the quartzose ore. A trachyte intrusion is always found near by, and narrow apophyses of the same rock form the walls of the antimony deposits, or cut through the ore masses in a direction parallel to or forming an acute angle with them. The antimony deposits consist of a dark, very finely crystalline ground mass of quartz, intimately intergrown with tufts of stibnite. The dark colour of the quartz is due to microscopic particles of hydrocarbons. Separating the deposit from both roof and floor is frequently a layer of clay, and sometimes clay fissures or stringers of calcite cut obliquely across the ore-bodies. The stibnite has mostly been superficially altered into stibiconite or valentinite, but sometimes the quartz merely contains the hollow moulds of the sheaves of stibnite. In places the quartzose ore has been crushed and re-cemented by quartz or calcite; there are also irregular druses, lined with quartz crystals and with here and there minute crystalline aggregates of native sulphur and crystals of senarmontite.

It is probable that these stibnite-quartz ore-bodies have been formed by hot siliceous waters rising up and along the contact between the limestone and slate, which deposited their contents not only in the fissures and clefts, which formed their main channel, but also in the joints of the limestone, replacing it entirely here and there.

In the mines of Kik and Stolitza tufts and stringers of stibnite, with quartz and calcite, occur in decomposed trachyte. With it are associated smaller quantities of orpiment and barytes [116/p. 48].

At Rivinè, a compound antimony vein occurs in the slates, dipping 30°. Between the two parallel bounding fissures, which intersect the stratification and schistosity of the country-rock, lies a zone, sometimes over 3 ft. in thickness, of very numerous stringers, mostly transverse, like the rungs of a ladder. The transverse fissures are cut off at the two wall

fissures and are rich in stibnite, with quartz and calcite. The foot-wall fissure is always the richer, the hanging-wall being mostly barren. Outside the zone enclosed by the leading fissures only barren calcite stringers occur. This deposit appears to be of the ladder-vein type.

The Zajatcha mines have been worked intermittently for a considerable period. There is a small smelting plant here. Stibnite occurs in acicular masses in quartz either as stringers in altered trachyte, or as stratified masses overlain by thick bedded limestones and underlain by compact limestone. Stibnite has also been worked from ancient times in the adjoining villages of Borina, Brasina and Dvorska. At Brasina, much native sulphur is associated with the stibnite.

At Dobri Potok, near Krupanj, stibnite is found in well-formed needles in large masses in limestones (probably Cretaceous) overlain by shales near numerous trachytic intrusions. There are smelting works close to the mine. From 1908 to the outbreak of war in 1914 a Serbian company treated 3,000 metric tons of ore, which yielded 18 to 25% antimony. The stibnite mine of Pyravina, at Lipenovits, east of Krupanj, was worked on a small scale for ten years prior to the war, the ore being smelted at Dobri Potok. There are other antimony mines, now not working, in the same region. Stibnite was formerly worked in the Podgorina mines, west of Valyevo, where antimony veins occur in Cretaceous limestone. In 1891, an English company raised about 50 metric tons of sorted ore from here.

At Bela Reka, N.E. Serbia, are quartz veins carrying stibnite with a little gold in crystalline schists in close association with intrusive andesites.

Stibnite occurs in quartz veins in Central Serbia.

In Slovenia, stibnite veins occur in the Carboniferous formation, and have been mined on a small scale.

In Croatia, stibnite occurs in small quantities at the Samobor siderite mines.

In Bosnia, antimony ores have been met with in paying

quantities in the Srebrenitsa argentiferous galena and blende mines. At Cemernitsa, near Fojnitsa, in Central Bosnia, six parallel stibnite veins are found in a broad metalliferous belt in Carboniferous sandstones and shales. They occur in close relationship to intrusive masses of quartz-porphyry. The principal gangue is quartz. There are three zones in the veins. The central zone consists of clear quartz with needles of stibnite; this is surrounded by a second zone of quartz with hæmatite and a little cinnabar; the outer zone consists of quartz and stibnite. On the surface the stibnite is very frequently altered to senarmontite. The ancient miners appear to have worked these veins largely for the gold and silver contents. Two typical antimony ores from Cemernitsa gave the following percentages: Antimony, 42·37 and 53·98; iron, 3·27 and 5·32; zinc, 18·86 and 8·63; sulphur, 27·20 and 28·20; quartz, 8·0 and 2·40; silver, a trace and 0·026.

At Prozer, in Central Bosnia, antimony ore in association with cinnabar occurs in a group of veins in Triassic limestones.

In Dalmatia, in the neighbourhood of Spizza, in the extreme south of the province, stibnite occurs in Triassic limestones [116/p. 47].

At Allchar, near Bitolje, in Serbian Macedonia, there is a zone of dolomitized limestones and mica-schist, which is irregularly mineralized with stibnite and realgar. The hanging-wall of the deposit consists of mica-schist and the foot-wall of dolomite and limestone. The ore occurs in stringers and lenses without gangue. The belt is 2½ miles in length, and the width of solid ore at times reaches 5 ft. On the south is stibnite with alteration minerals; on the north are realgar and orpiment enclosing some kernels of arsenopyrite. Near the deposit the dolomite is highly altered with the formation of sulphur and selenite. The deposit is a metasomatic one [31/1, p. 774] [102/p. 784]. Vrbait, a mineral rich in thallium, was described, in 1912, as occurring in small quantities in association with the antimony ores [116/p. 48].

The production of antimony in Serbia appears to have been

small hitherto. Statistics of some years are lacking. The output of regulus and oxide amounted to 4,725 metric tons in 1904, and to 297 tons in 1912. The greater part of the product was formerly shipped to the United States [112/p. 51]. The production of antimony is given as 725 metric tons in 1917, and the exports as 831 tons in 1920 [6/1922].

ASIA

AFGHANISTAN

Stibnite and valentinite are said to occur in Afghanistan in abundance among the hills north of Kil'Abdullo, Quetta-Pishin, Baluchistan [34/p. 164]. Antimony is reported to occur in black slates at Kinchak, and in limestone at Fuligird [33/p. 10].

ASIA MINOR

In Anatolia, stibnite occurs in irregular veins usually interbedded with schists and gneisses. Mercury is associated with the antimony in some instances (*see* below and Imperial Institute monograph, *Mercury Ores*, 1923, p. 57).

In the *vilayet* (province) of Brusa, the Gomekchiftlik antimony mine, *sandjak* (district) of Kutaya, 15 miles E. of Gedis, has irregular veins of stibnite in an amphibole-gneiss passing into a granular limestone. They have been worked opencast. From 1901 to 1908, the annual production was about 500 tons. Two other deposits occur in the sandjak of Balikestri; one is 4 miles S.W. of Bali; the other 4 miles N.E. of Ivrindi. In the sandjak of Brusa, quartz lenses with stibnite embedded in argillaceous schists occur at Demir-Kapou, 5 miles S.W. of Sultan-Chair. In the sandjak of Belejik, antimony has been found in small lenses in gneiss at Seuluklu, between Ainegeul and Bilejik.

In the sandjak of Smyrna, vilayet of Aidin, the Djinlikaya mine is situated on the N.W. slope of the Baliamboli Dagh, 60 miles E.S.E. of Smyrna (port). Here several antimony veins occur in crystalline schists. The only deposit hitherto worked consists of two neighbouring veins, which are sometimes united. The fractures are at the contact of two different kinds of schist. The compound vein is filled with crushed schistose material and a mixture of stibnite and pyrite, the

proportion of the latter increasing with depth. One pocket from this deposit yielded 4,000 tons of antimony ore [117]. Near by, in the villages of Kalikoï and Kouré, micaceous and argillaceous schists contain several pyritic veins with, occasionally, traces of mercury, or with cinnabar-bearing threads. In 1898, the Djinlikaya mine produced 500 tons ; in 1901, 400 tons ; and in 1911, 1,500 tons of 50% ore. The deposit was worked energetically during the war.

About 1902, work was commenced at the antimony mines at Kordilio, on the N. side of Smyrna (port). The first production amounted to 100 tons. Afterwards there was a considerably increased output. Antimony also occurs on the S.W. slope of the Kizil Dagh, 16 miles S.W. of Smyrna. According to Weiss [118], the deposit is a complex of small veins and strings of pockets in a cherty somewhat calcareous gneissose-looking rock. The workings are shallow opencast. The mine has produced at the rate of 500 tons of ore per annum.

Deposits of antimony ores, associated with lead ore, are reported to occur in the vicinity of Karahissar, vilayet of Sivas [119] [31/1, p. 758] [112/p. 55].

The total annual production of stibnite in Anatolia in 1919 was estimated at 2,500 metric tons [119]. In 1906, the exports of stibnite from Asia Minor amounted to 1,036 tons. The production in 1912 is reported to have been 677 tons of ore. In 1914 and 1915, Asia Minor is stated to have produced 33 and 42 tons respectively of antimony [6/1922, p. 44], but these figures are probably too low. From 1917 to 1921 the total output was 2,000 tons.

China

China has been the principal antimony-producing country of the world for the last quarter of a century. The most important deposits are in the Province of Hunan, South China, and supply about 90% of the total Chinese output. Antimony deposits are also found in the provinces of Hupeh, Yunnan, Kweichow and Kwangsi.

The antimony industry of Hunan Province was described by Wheeler in 1916 [7]. Hsi-K'uang-Shan, by far the most important antimony deposit of the world, has been more

recently described by Tegengren [119A]. It is in the very centre of the Province, at lat. 27° 48′ N. and long. 4° 53′ west of Peking, at an altitude of about 2,300 ft.

The formation consists of sedimentary rocks, ranging probably from Silurian to Carboniferous. The oldest rock consists of stibnite-bearing quartzitic sandstone (Silurian or Devonian) about 165 ft. in thickness. Above this is hard quartzose slate 65 ft. thick; then come thinly-bedded and massive limestones, about 1,280 ft. in thickness, which are capped by sandstone and dark shale (often coal-bearing) 65 ft. thick. No igneous rocks have been observed near the mines. The rocks have been folded into anticlines and synclines trending N.N.E.–S.S.W. and dipping 20°–30°. There is also a well-marked line of faulting, wherein the strata are often fissured and brecciated, and have been displaced vertically some 300 ft. The primary ore mineral is stibnite in prismatic or acicular crystals or in pure crystalline masses. Quartz is the only gangue mineral. Pyrite and cinnabar occur rarely in the breccia. Secondary valentinite and cervantite occur as white or yellowish porous masses or as beautiful pseudomorphs after stibnite. The ore is irregularly scattered in the quartzitic sandstone layer, the rocks often being distinctly fractured and brecciated, owing both to folding and faulting. On the whole the ore shoots are most abundant underneath dome-shaped vaults formed by cross-folding. Some layers are compact and impregnated only with minute needles of stibnite; others, which are brecciated, contain irregular veinlets, veins and lenticular bodies of almost pure stibnite. The deposit may be regarded as largely a replacement one.

The ore is remarkably pure; iron is present to the extent of about 0·5%, arsenic seldom reaches 0·1%, and lead, copper and zinc make up about 0·5%. Tegengren estimates the average antimony-content of the ore-bearing quartzitic sandstone at about 6%.

These antimony deposits strongly resemble the mercury occurrences of N.E. Kweichow and S.E. Szechuan, which are also confined to similar brecciated anticlines.

Along the 2,000 yd. of lode are distributed the workings of

about 80 Chinese companies and owners. A maximum depth of 300 ft., measured on the incline, had been reached in 1915. The mines are worked in a very primitive way. The ore, cobbed and hand-sorted, has an average content of 60% antimony. The fines, etc., are hand-jigged, the concentrate giving 45% metal.

The production of this field in 1915 amounted to a few hundred tons of high-grade ore, and about 1,000 tons of "crude" (liquated stibnite) per month [7]. In 1921 the monthly production, besides some ore, was about 1,700 tons of crude, and 200 tons of regulus. The aggregate production of this deposit may be estimated at more than 105,000 tons of pure antimony, corresponding to about 200,000 tons of ore of 55% grade. This antimony deposit alone supplied nearly 40% of the world's production before the Great War, and has probably supplied a still higher percentage during and since the war [119A]. It has been estimated that this field alone contains more than 2,000,000 tons of pure metal [120].

The Pan-Ch'i mines, next in importance, are 25 miles south of Chan-Ch'i, on the Tze River. The formation consists of clay, slates and shales with occasional layers of quartzite, tilted and bent by a granitic intrusive, which has produced well-developed joint-planes in the sedimentary rocks, which have otherwise undergone little alteration. The strata strike E.–W., and the joint-planes N.E.–N.N.E. In 1915, four nearly vertical ore-bodies were being worked here, all of the fissure-vein type. The strike is E.N.E.–N.E., and the veins rarely exceed 15 in. in width. The filling consists of quartz or inter-laminated schist and quartz, with a narrow seam of stibnite on the foot-wall, accompanied by a strong clay selvage. The pay-ore occurs in comparatively short shoots, which have been followed down to depths ranging from 150 to 550 ft. The lowest levels show a considerable decrease in the length of the shoots, although the fissures are still strong and well defined. The cobbed and sorted ore contains about 30% antimony. The output, about 400 tons monthly, is sent to the Hua Chang Co.'s works at Chang-Sha.

The Wu-Ch'i mines lie 52 miles east of Shenchowfu (or

Yuän-Ling-hsien) in the rugged country dividing the Yuan and Tze rivers. The formation is similar to that at Pan-Ch'i, but bent into folds dipping S.W. and N.E.—the cleavage or joint-planes are steeply inclined at right angles to these. The deposits are fissure-veins striking N.-S. and E.-W., the latter appearing to be the more productive ones. The veins are of quartz with included fragments of slate. The stibnite usually appears as a seam on the foot-wall, which is regular and well defined, whilst the hanging-wall is indistinct. In 1915, the vein in the western workings had been driven on for 500 ft., and had been stoped out to water-level, 130 ft., where it is from 3 to 4 ft. wide. In the eastern workings the vein had been worked to a depth of 450 ft., measured on the dip, the width being 3 ft. The ore, cobbed and sorted, yields two grades: viz. of 30% and of 20% metal content. It contains traces of gold. The mine was formerly worked for gold. Coal was recently discovered in the field, which may soon prove equal to that at Pan-Ch'i in importance.

The An-hua mines are to the west of the Tze River, about 50 miles west of An-hua, and to the north of Che-pu. The veins are of a similar type to those of Pan-Ch'i, and in 1915 supplied about 100 tons of 50% ore per month.

The Chiang-Ch'i-lung mines are 14 miles S.S.E of Che-pu. They are all on one vein traceable for 3,000 yd. along a hill range. The country rock, apparently the same as that at Wu-Ch'i, has been altered by intrusives to a slaty schist. The vein strikes with the "country," N.E.-S.W., and dips S.E. 60°-80°. It is narrow and made up of alternations of quartz and schist. The stibnite is in seams and stringers in the quartz, and is plentifully disseminated in small crystals in the schist. The deepest workings in 1915 were 375 ft. below the outcrop. The workings show the pay-shoots to be short, and rapidly contracting, and in depth pyrite is replacing stibnite. Early in 1915 the output was 75 tons per month of products ranging from 10 to 60% antimony.

At Lung-Shan, antimony deposits, stated to be in limestone, are principally owned and worked by the Pao-li Smelting Co., of Chang-Sha. In 1915, the output of picked ore and concentrate is said to have exceeded 100 tons per month.

New deposits, including a deposit of native antimony, have been discovered in the Pingkiang Magistracy, about 90 miles N.E. of Chang-Sha.

Antimony deposits also occur in Hu-peh, in T'ungjên, in Kweichow, and at Wen-Shan and Ami, in Yunnan.

According to W. R. Schoeller (*Jour. Soc. Chem. Ind.* May 13, 1913) the antimony ores of Hu-peh and Kweichow contain more arsenic than those of Hunan.

In China a few thousand tons of high-grade ore are shipped direct, but the bulk of the production is marketed in the form of "crude" (liquated stibnite) and "regulus" (unrefined metal). The regulus is produced principally from the lower-grade ore, containing about 30% antimony, from liquation residues, and to a less extent from cervantite. The Hua Chang Co., who hold a monopoly for the production of regulus within a radius of 36 miles of Chang-Sha City, use the Herrenschmidt furnace, of which they own the patent rights for China.

In the following table are shown the exports of antimony ore, crude and regulus, from China from 1915 to 1922. Prior to 1915, there were only two sub-divisions, viz. ore and crude, regulus and refined.

Exports of Antimony Products from China

(Long tons)

	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
Antimony ore	1,645	11,576	3,798	473	570	1,329	1,158	1,814	2,018
Antimony, Crude	15,406	11,780	19,818	1,678	2,101	4,484	2,493	1,579	2,882
Antimony, Regulus	5,955	10,306	14,584	14,151	6,109	9,570	13,463	11,963	11,495

[121]

French Indo-China

Stibnite has been found between Quan-Yuen and Moucai in Tonkin. It has also been found in rounded stones or boulders of varying size, which have a peculiarly smooth yellowish-brown surface, and have been accumulated in the beds of torrents [3/p. 56].

There are productive deposits of possible future importance in French Indo-China. In 1916 these deposits produced 1,437 tons of antimony ore having a metal content of 642 tons. Smelters were operated by the firm of Schon and Rhay, and both native and Chinese ores were treated. From 1914 to 1917, inclusive, 2,329 metric tons of antimony ore were exported to France [112/p. 54] [17/1919, p. 308].

JAPAN

For eighteen years, or from 1882 to 1899, Japan produced 29,987 long tons of antimony, an average of 1,666 tons per annum. Soon after 1897, when the rich mines in Hunan Province, China, were first opened up, the production of domestic ores fell off considerably, but large quantities of the Chinese ore and crude were treated in Japan, much of the product being shipped to the United States during the war.

The principal antimony deposits in Japan are found in Mesozoic strata, which extend from the Province of Yamato, in Honshu, through Tosa and Iyo, in Shikoku (island), to Hyuga and Osumi, in Kyushu. Antimony deposits also occur in Palæozoic rocks, as at the Nakase and Nakagawa mines, Tajima, in Honshu, and the Arahira mine of Hyuga, in Kyushu. They are also found in sedimentary rocks near their junction with intrusive quartz-porphyry, or within the eruptive itself, as at the Amatsutsumi mine, Hyuga. They occur only occasionally in crystalline schists, as at the Ichinokawa mine, Iyo, and are equally rare in Tertiary rocks.

Generally speaking, these distributions are entirely included in the South Japan Arc, and are especially plentiful on the Outer Side.

At Kano, Province of Suwo, Island of Honshu, antimony veins from 2 to 9 ft. wide are traceable in Mesozoic schist for a length of 6,000 ft. At Totsugawa, south of Kyoto, an antimony vein occurs in quartzitic and graphitic schists of Palæozoic age. Other antimony-bearing mines on the main island are Nara and Yamaguchi (Mesozoic), and the Nakase mine, Tajima, where a gold-bearing stibnite vein occurs in Palæozoic rocks.

In the Ichinokawa mine, Province of Iyo, Shikoku, antimony veins traverse crystalline schists, the gangue being quartz and a little calcite. Pyrite occurs occasionally. The veins are banded with druses, which contain very large beautiful crystals of stibnite [122/p. 106] [3/p. 56].

Antimony veins also occur in the Amakusa Island, on the west coast of Kyushu. Rein, in 1875, saw one at Takahama, which measured 6 to 8 in. in thickness [123].

In 1874, four mines were producing antimony on a very small scale. The first official output was recorded in 1876 with 34 tons of antimony. In 1887 the production amounted to about 50 tons. In 1888 and 1889 the production of antimony and stibnite was 148·7 and 190·5 tons, respectively; in 1890, 1891 and 1892, that of antimony was 95, 62 and 42 tons, and of the sulphide, 1,773, 2,174 and 1,324 tons, respectively [89/p. 616].

In 1907, the output of the chief mines amounted to 372 long tons of ore (Kano), 113 tons of crude (Tenga-iwa and Hanta), and 77 tons of refined (Ichinokawa). In 1908, the production was 259 tons of ore (Kano), 60 tons of crude (Tenga-iwa, Hanta and Ichinokawa), and 118 tons of refined (Ichinokawa). The total production of domestic ores in 1908 amounted to 138 long tons of refined antimony and 73 long tons of crude metal. After this, owing to the exhaustion of the richer ores, and to the fall in the price of the metal, very few antimony mines were working in Japan. From 1876 to 1908 inclusive, the production of antimony is given as 34,957 long tons [122/pp. 54, 106].

From 1912 to 1919 inclusive, Japan produced 25,916 long tons of antimony, no less than 25,392 tons of this having been obtained in the war years 1915, 1916 and 1917. No production is recorded in 1920 and 1921 [124/p. 64]. This antimony was almost entirely from Chinese ore.

PERSIA

In the Afshar district of Persia stibnite occurs in veins in limestone, generally along Tertiary folds. The associations are galena, tetrahedrite, cinnabar and realgar. Stibnite is called *surmeh* in Persia [31/1, p. 773].

AFRICA

Algeria

A considerable quantity of antimony ore has been shipped from Algeria to France in past years, and during the war period the Algerian deposits were the mainstay of France so far as this particular metal was concerned.

The better-known deposits, which occur in the Province of Constantine, Eastern Algeria, have been described by De Launay [31/**1**, p. 770]. The principal deposit is that of Djebel Taya, about 20 miles west of Guelma, where stibnite, with galena and cinnabar as accessories, fill thin vertical fissures and joint-planes in limestone (Lower Cretaceous), near marls. At the contact itself stibnite occurs as radiated balls weighing up to 440 lb. The gangue consists of quartz, calcite and barytes. Stibiconite is found near the surface. In 1897, Djebel Taya was producing 731 tons of antimony yearly.

The Djebel Bebar deposit, some 6 miles N.W. of Guelma, occurs, filling cavities in limestone of Neocomian (Lower Cretaceous) age. The stibnite, associated with cinnabar and smithsonite, has a gangue of quartz and barytes.

At Oued Ali, 10 miles N.N.W. of Guelma, limestone containing *Inoceramus*, of Senonian or Upper Cretaceous age, has fissures incrusted with stibnite, partly oxidized, and cinnabar.

At Bou Zitoun, about 4 miles north of Guelma, are bunches of smithsonite, with stibnite and barytes, filling cavities in limestone of Lower Cretaceous age.

At Djebel Nador, 14 miles E. 40° S. of Guelma, the rare mineral nadorite (a chloro-antimoniate of lead) is associated with smithsonite, filling cavities in an irregular deposit in gypsiferous clays and travertine of the Upper Devonian. The outcrops especially were formed of smithsonite with galena, cerussite, mimetite and nadorite. Prior to the war, the last mineral was the chief product mined.

At Sidi-Rgheiss are deposits of senarmontite, which have been mined at Sempra and at Djebel Hamimat, in alternating beds of black limestone and bituminous schistose marls (Gault—Upper Cretaceous). With the senarmontite are associated a

little stibnite, antimonial and somewhat leady smithsonite and cinnabar. The mineral forms irregular masses, parallel to the bedding-planes, which are vertical and striking E. 60° S.; the deposits are formed especially at the contact of the limestone and marls. Limestone is frequently found enveloped by ore, which indicates that the antimony deposit has been formed by replacement. This deposit—worked from time to time—has furnished four varieties of antimony oxide ore: (1) Compact, of a milky-white colour and of a stony aspect resembling white lead; (2) granular, containing geodes of octahedral crystals, up to more than 1 in. in diameter; (3) crystallized; and (4) disseminated as free crystals in clay. The stibnite, which is scarce, appears in little silky tufts, sometimes partially converted into kermesite, when it is of a brownish-red colour. Sometimes large octahedra of senarmontite occur agglomerated into blocks of many pounds weight, and coloured black by very fine capillary needles of stibnite. Elsewhere, the senarmontite, in transparent octahedra, coats cavities, which occur in masses of cottony stibnite, and is accompanied by needles of kermesite which impart a red colour to the sulphide.

At Sensa or Sanza, about 2½ miles west of Hamimat, is a deposit of valentinite, similarly the result of the alteration of stibnite. Sometimes the extremity of the fibres of valentinite is of a bright yellow colour, that mineral itself having been altered into *volgerite* or *cumengite* (a hydroxide of antimony). Specimens, also from Sensa, show large rods of the hydroxide, transformed from fluted crystals of stibnite, and surrounded by a sheath of cinnabar [125].

From 1904 to 1910, the production of ore (principally from Taya and Hamimat) amounted to 540 tons of stibnite and 1,150 tons of senarmontite and valentinite. From 1912 to 1923, inclusive, 75,647 metric tons of ore were produced, containing approximately 28,448 tons of metal. It will be seen from the following table that the best output was in 1916, with 28,473 tons of ore, and the lowest in 1921, with 320 tons.

Production of Antimony in Algeria

(Metric tons)

	Ore.	Metal content (approximate).		Ore.	Metal content (approximate).
1912 [1] . .	4,661	1,771	1918 [1] . .	7,920	2,772
1913 [1] . .	582	233	1919 [1] . .	2,160	756
1914 [1a] . .	1,100	400	1920 [2] . .	2,966	1,038
1915 [1a] . .	9,022	3,428	1921 [2] . .	320	112
1916 [1a] . .	28,473	11,176	1922 [3] . .	1,645	576
1917 [1] . .	16,248	5,686	1923 [3] . .	1,500	500

[1] *Min. Res. U.S. Geol. Survey*, 1919, Pt. I, p. 310.
[2] *L'Echo des Mines et de la Métallurgie*, Feb. 20, 1923, p. 87.
[3] *Ibid.*, Sept. 20, 1924, p. 407.
[1a] Exports.

NORTH AMERICA

Cuba

Silver-bearing stibnite is found in the Isle of Pines, Havana [126].

Mexico

Mexico has produced a considerable quantity of antimony for many years. During the Great War, when there was naturally an increased output, antimony ore was mined principally in the Catorce and Charcas districts, San Luis Potosí; in Querétaro, and in the Altar district, Sonora. The deposits of the Sierra Catorce (San Luis Potosí and Querétaro) consist of mixed sulphides and oxides (principally the latter) carrying 5 to 50% antimony [112/p. 46], which occur in limestone or at the contact of limestone and porphyry [28/p. 603]. At Rio Blanco, Querétaro, stibnite occurs in limestone (Cretaceous), and is associated with pyrite and cinnabar in a quartz matrix.

The antimony deposit, about 50 miles west of El Altar, Sonora, was worked about 40 to 45 years ago. It then lay idle for many years, but was reopened in 1917 with the aid of American capital. The formation is quartzite, limestone and altered eruptives. The veins run N.–S., N.E.–S.W. (dip westerly), and E.–W. (dip southerly). They frequently intersect, and, at the points of junction, the ore, which is stibiconite, is apt to occur in bunches or pockets. Near the surface the ore was in loose stones (*boleos*). One vein, proved

to a depth of 84 ft., strikes N.E.–S.W., dips S.E. 52½°, is 2 to 3½ ft. wide, and consists of layers or bands of black, yellow, grey and brown stibiconite, frequently much mixed with quartz. The country-rock is soft and decomposed, and is probably an eruptive. Another vein, proved to a depth of 150 ft., runs E.–W. with a high southerly dip, and is composed of bands of dark-coloured stibiconite and quartz. At the bottom the vein is very quartzose and low in grade. A parcel of 50 tons of hand-picked ore yielded 53% antimony. The ore was reduced in a small cupola furnace at Oakland, California [127].

The maximum monthly capacity of the mine in 1917 was said to have been 400 tons per month. The oxide is said to carry less than 0·5% of other metals. Car lots averaged 46 to 52% antimony. The ore was hauled by wagons 90 miles to Santa Ana railroad station, and from there was shipped to the smelter of the Western Metals Co., near Los Angeles [128/p. 663]. The ore carried some silver, the percentage of which is said to have increased with depth.

According to Rangel and Terrones [129], antimony ores are abundant in Durango, and are frequently associated with lead-silver ores. Moreover, there are deposits formed almost exclusively of stibnite, senarmontite and valentinite, but in these, lead ores commonly occur in depth. The best specimens of stibnite are from the Nazas district. None of the Durango deposits appears to have been mined.

Antimony ore has been shipped from the Tejocotes mine, Tlaxiaco, Oaxaca [130].

A large deposit of jamesonite occurs at La Sirena, near Zimapan, Hidalgo, which has been described by Lindgren and Whitehead [131].

The deposit outcrops along the upper part of an almost vertical precipice of limestone (Cretaceous), 10 miles N.W. of Zimapan, and appears as a tabular mass 2 to 100 ft. in width, and at least 1,000 ft. in length. The deposit consists of pyrrhotite, pyrite, blende and jamesonite, with some minute grains of galena and chalcopyrite. The chief gangue minerals are quartz, calcite, amphibole, apatite, danburite, albite, fluorspar and garnet. The ore will probably average 8%

lead, and 4% antimony, from 0·5 to 2 oz. silver, and 0·01 oz. gold per ton. Pure jamesonite contained 3 oz. silver, and one sample with much arsenopyrite yielded 16 oz. silver per ton. An altered porphyry dyke occurs below Punta David, where the ore adjoining it is only 2 ft. wide and contains much pyrite. The order of succession here appears to have been: Pyrite, arsenopyrite, blende, jamesonite and calcite. Another dyke occurs in the central part of the deposit. The limestone is metamorphosed along the dyke; danburite has replaced limestone, and is in turn replaced by jamesonite. In addition, albite, pyrite, pyrrhotite, and garnet as grossularite, are present. The order of succession at this point appears to have been: Albite and quartz, apatite, fluorspar, pyrrhotite, blende, jamesonite. The authors of the paper believe that the ore-body should be classed as a high temperature (probably between 500° and 575° C.) replacement, presenting a most important link between contact-metamorphic and hydrothermal-replacement deposits.

Since 1918, the deposit has been owned by the (U.S.) Antimony Corporation. There has been some exploration and development, and, although the great lead-antimony deposit mass does not seem to persist, a silver-lead antimony vein was disclosed [132/p. 1874], particulars of which are lacking.

Stibnite is not infrequently present in the outcrops of the silver-bearing veins of Taviches, Oaxaca, where it is associated with pyrargyrite. Thus, in La Cueva surface working small spots (*moscas*) of pyrargyrite in white opaque or transparent quartz are associated with stibnite, and in the San Angel working moscas of pyrargyrite are associated with stibnite, calcite and gypsum. The country rock is hornblende-andesite (Tertiary). The branches of one of the large lodes contains at and near the surface stibnite in small lumps and pockets, which was being mined by the *gambucinos* (tributers) about 1893 [133].

United States

Deposits of antimony ore are by no means rare in the United States, but they are usually small and not well situated as regards transport, so that hitherto they have only been worked

intermittently, or when markets were favourable, as, for instance, in 1906. During the war, when antimony was in great demand for shrapnel, and the price of the metal rose to a phenomenal extent, many of the already known deposits were reworked, and some new ones were discovered and mined. From 1915 to 1918 the United States produced 10,750 short tons of antimony ore containing 4,310 tons of metal. There has been no production of ore since 1918. For many years the United States has produced a good deal of antimonial lead from lead skimmings as a by-product of the lead-smelting industry. The antimony content of this lead amounts to some 2,500 to 3,500 tons per annum. The principal producing states during the war period, in order of importance, were Nevada, California, Alaska, Washington, Oregon, Idaho and Arkansas; whilst Utah and Arizona produced insignificant amounts.

Alaska.—The antimony deposits of Alaska have been described by Alfred H. Brooks [134]. Stibnite is widely distributed in the Territory, having been noted in 67 localities. Brooks classifies the deposits as follows: (*a*) Siliceous gold-bearing stibnite lodes—the only type thus far developed on a commercial scale; (*b*) stibnite-cinnabar lodes—the principal one, known as the Parks Prospect, has been mined for mercury, and is described in the Imperial Institute monograph, *Mercury Ores* (1923, p. 68); and (*c*) stibnite-galena deposits—about which little is known, but they appear to be replacements of crystalline limestone. The chief localities from which antimony ore has been raised are Fairbanks, Kantishna and the Seward Peninsula.

In the Fairbanks district, gold-antimony lodes are found in two mineralized zones known as the Cleary and Ester. In the Cleary zone most of the rich lodes are found in an E.-W. system, which is crossed by a N.-S. system, also containing gold and antimony. The country rock in both areas is mica-schist or quartz-schist, probably of pre-Cambrian age. All the antimony deposits occur in zones of fracture, sometimes appearing as simple veins and sometimes as sheet zones. The typical occurrence of stibnite is in shoots and kidneys, more or less irregularly distributed along the vein or sheet zone.

White and vitreous quartz is the principal gangue mineral; some lodes contain a little calcite. The chief accessory minerals are pyrite, arsenopyrite and galena. Secondary antimony minerals are cervantite and stibiconite. The stibnite is usually finely granular, with fibrous masses or acicular crystals here and there, or there is a confused aggregate of acicular crystals, or the mineral is in coarse and fine columnar form interspersed with fibrous and granular aggregations.

A number of antimony mines in the district were worked in 1916, but all of them except the Chatham mine were closed in August of that year. At the Chatham mine a nearly vertical antimony vein, striking N. 70° E., 18 in. wide, is said to cut the main gold-quartz vein of the mine at an angle of 85° [135].

At Kantishna, the ore-body of the Taylor mine is described as a reticulated stockwork of quartz and stibnite, with irregular bunches and bosses of decomposed clayey schist. The stibnite is in veins and veinlets of almost pure mineral, up to 2 ft. wide, and in irregular lenses and bunches [136].

In the Seward Peninsula, antimony is found in later quartz veins, which cut metamorphosed schists. They all contain some gold and generally a little pyrite and galena. In the Sliscovich mine, Nome district, the stibnite appears to be later than the quartz, and apparently contemporaneous with at least a part of the gold. The country rock is a dark-green chloritic schist [134/p. 51].

The formation of the stibnite lodes of Alaska appears to have taken place in Tertiary times. They occur in igneous intrusives, or in country-rock adjacent to intrusives.

The antimony production of Alaska between 1916 and 1918 amounted to 2,492 tons of stibnite. There are large reserves of antimony ore, but they are mostly in the less accessible parts of the Territory. Their future development depends on the market and on cost of transportation [137].

Arizona.—Stibnite is found in quartz veins with gold in the Bradshaw Mts., Yavapai Co. [138/p. 410]. In the same county it is of common occurrence in silver-bearing veins, and is found in the Vanderbilt mine in the Cerbat district,

Mohave Co. [15/p. 6]. Antimony in economic quantities has hitherto not been found in this state.

Arkansas.—The antimony deposits of Arkansas are in the northern part of Sevier Co., near the Oklahoma boundary. The rocks are thinly bedded sandstones and sandy or muddy shales of Palæozoic age. The vein of the Bob Wolf mine strikes about E.-W. The stibnite occurs here and there in blades parallel to the walls, and between combs of quartz. The ore at the Conboy mine, having a similar banded structure, is said to have been rich in silver [139]. According to Mitchell [140], the veins, which are parallel to the steeply dipping beds, with slight replacement of the walls, closely follow on the strike of the sedimentaries. The bands of quartz or calcite in the veins are sometimes disseminated with stibnite. The order of deposition in one vein examined seems to have been: Quartz; stibnite; stibnite, quartz and calcite; stibnite; quartz. The ore also occurs in small lens-like masses in the fault-zones. About 2 miles to the S.E. Mitchell found a dyke of the basic rock, ouachitite. These deposits seem to resemble the stibnite veins of Bolivia (*see* p. 87). The stibnite in this area is found associated with jamesonite, zinkenite, galena, pyrite, chalcopyrite and siderite. From 40 to 115 ft. from the surface, blende, etc., began to come in. In 1892, the shaft of the Otto mine was 230 ft. in depth, and still in good ore. According to local tradition, this mine produced over 1,000 tons of antimony [139/p. 250].

Stibnite also occurs near Antimony, Howard Co., forming the eastern part of the antimony-bearing area.

California.—The greater part of the output of California during the war period was from two mines in Inyo and Kern counties; some ore was raised from San Benito and San Bernardino counties. At San Emigdio, Kern Co., a quartz-stibnite vein from a few inches to several feet in width, occurs in granite, and has afforded some metal [141]. The occurrence of native antimony in the same county has already been mentioned (*see* p. 5).

Idaho.—In the Pine Creek district of Idaho, antimony veins have a wide distribution in Pritchard rocks (Algonkian). The veins strike in various directions. Stibnite and quartz,

associated with pyrite, are the dominant minerals. The stibnite replaces the slate and the vein-quartz. The Cœur d'Alene Antimony Mining Co. shipped a considerable quantity of ore during the Great War from a vein occupying a fault or shear-zone in black slates, striking N. 60° E. and dipping N.W. 35° to 60°. Concentrate sold in 1916 yielded 36·36% antimony and 0·24 oz. gold per ton. The greatest depth attained was 170 ft. on the dip of the vein. The stibnite ore was 1 to 5 ft. wide in a gangue of quartz and unreplaced slate. The vein of the Star Antimony group is 3 ft. wide, and is contained in a fault zone from 4 to 8 ft. wide, striking E.-W. and dipping S. 26° to 60°. The centre of the vein consists of a rich streak of crystalline, though sheared, stibnite 1 to 28 in. wide, the rest of the vein being formed of slate with disseminated stibnite. The high-grade shipping ore assayed 55% antimony [142]. The Cœur d'Alene antimony ore contained 12 to 60% antimony; 8 to 10 oz. silver; and from 90 cents to $1 in gold value [15/p. 6].

Antimony ore has also been obtained from other parts of Idaho [143/p. 512], although not in any quantity.

Gold is associated with antimony at the Gold Hill mine at Quartzburg. The vein filling of small fissures in a rhyolite-porphyry dyke in granite is chiefly quartz sprinkled with stibnite and pyrite. The gold is scattered through the stibnite in a finely divided state [144].

Montana.—Stibnite is abundant in the primary silver-gold ores of the Granite-Bimetallic lode, near Philipsburg [138/p. 411].

Nevada.—In Western Nevada, stibnite veins with a gangue of fine-grained and drusy quartz intersect flows of rhyolite and basalt. As a rule, the stibnite is beautifully crystallized in acicular and prismatic forms, and is often accompanied by a little pyrite, blende and arsenopyrite, sometimes also by tetrahedrite and cinnabar. Such veins carry a little silver and less gold [145]. There has been a small output from near Lovelocks, Humboldt Co., the Sutherland mine being the principal producer. The ore is said to carry a considerable amount of silver [143/p. 512]. The Beulah and Genesee mine, near Austin, Lander Co., showed 3 ft. of nearly pure

stibnite, produced 700 tons of sulphide in 1891, and was worked in 1892 [141/p. 259]. The ore occurred in well-defined contact-fissures between shale (foot-wall) and calcareous sandstone and lime-porphyries (hanging-wall) [15/p. 6].

Of considerable geological interest are veins of argentiferous bindheimite, the so-called hydrous antimoniate of lead, in the Arabia district, Humboldt Co., described by Knopf [146]. The ore-bodies are fissure veins in granodiorite (possibly Cretaceous) and hornfels, the latter being metamorphosed shale, possibly of Jurassic age. In the hornfels the veins fray out into narrow stringers. The principal ore mineral is argentiferous bindheimite, which is sometimes in solid masses, and sometimes scattered through coarse milk-white quartz enclosing numerous microscopic prisms of tourmaline. The bindheimite is pseudomorphous after jamesonite. Some of it shows a delicate banding, which consists of an alternation of brown and yellow varieties. Bindheimite, as first pointed out by Cornu, is a mineral gel, and this banding appears obviously to be the result of the rhythmic precipitation due to hydrolysis of some diffusing compound—probably an iron salt—before the bindheimite gel had set. Valentinite, plumbojarosite (basic sulphate of lead and ferric iron), scorodite (hydrous ferrous arsenate—from arsenopyrite), cerussite and gypsum occur in the ore of the Montezuma mine, which contained 50% lead and antimony, and 80 oz. silver per ton. The ore-body of this mine trends E.-W., dips N. 45°, and appears to have been a large lens that pitched westward. The foot-wall is a large block of metamorphic shale enclosed in granodiorite. The main ore-body was 14 ft. thick and 90 ft. long. The workings are shallow, and the mine has been practically idle since 1875. The ore-deposit, which was originally jamesonite, was probably formed at high temperatures.

Oregon.—Some ore has been mined from Eckley, Curry Co., Oregon, which is said to carry high gold contents [143].

Utah.—The antimony deposits of Southern Utah have been described by G. B. Richardson [147]. They have been worked at irregular intervals since 1880, and it is reported that more than $100,000 worth of the ore has been shipped from the

property on Coyote Creek, Garfield Co. The ore of this mine consists of stibnite and its oxidation products (valentinite, and senarmonite) in flat-lying deposits in sandstone and conglomerate.

The chief zone of mineralization is in the sandstone, a few feet above the conglomerate. Lenses (" kidneys ") of ore occurred which ranged from several inches to 20 ft. in thickness. Gangue minerals were almost completely absent. The high-grade ore (50 to 60% antimony) has been worked out, but a large amount of low-grade ore has been left standing. The deposits have undoubtedly been derived from hot springs [145/p. 503].

Small radiating crystals of stibnite are found at Mercur [138/p. 411].

Washington.—Antimony has been mined in Okanogan and Snohomish counties [143/p. 512]. At Monte Cristo, in the latter county, stibnite is found intergrown with realgar, which Spurr regards as secondary. It generally occurs as free crystals, lining druses [138/p. 411].

SOUTH AMERICA

Argentina

Antimony has been found at Charillos, in the department of San Antonio de los Cobres, Province of Salta, Argentina [3/p. 55].

In the Sierra de Córdoba, a quartz vein carrying antimony occurs near the town of La Higuera. In contact with the vein is a deposit of granular limestone crossed by little veins of quartz, or impregnated with quartz. To the east appear gneiss and pegmatite. The antimony vein strikes N.W.–S.E., and dips E. The stibnite occurs as nests in the quartz, and is accompanied by some stibiconite [148].

Bolivia

Antimony minerals are occasionally found in the tin-silver-tungsten-bismuth lodes of Bolivia. Thus in the Oruru silver-tin district, Department of Oruru, tetrahedrite and jamesonite are the principal silver minerals, the latter being in thick tufts

of acicular crystals or as fine needles in druses in pyrite [147/p. 112]. In the Pulacayo silver district, Department of Potosí, stibnite and tetrahedrite are found in the silver veins [149/p. 130]. In the Portugalete (Tatasi) silver district of the same department tetrahedrite and jamesonite occur with galena, etc. [149/p. 133]. Besides the antimony minerals mentioned, stephanite and the rare lead-antimony minerals franckeite ($Pb_5Sn_2Sb_2S_{12}$) and kylindrite ($Pb_6Sn_6Sb_2S_{21}$) occur occasionally [149/p. 101].

The antimony veins proper of the same region are quite distinct from the above; they fill comparatively narrow fissures in black Palæozoic shales, and consist principally of stibnite in a quartz gangue. Sometimes galena is present, and sometimes the stibnite is auriferous [149/p. 87].

Antimony ore was raised from a mine at Palea, near La Paz, in the department of the same name in Northern Bolivia, in 1906, when the price of the metal was abnormally high. The mine was worked by adits. The veins were bunchy, but fairly persistent and often of good width. The ore, after hand-sorting, carried upwards of 50% antimony. A few unworked deposits were at that time known on the western side of Quimsa Cruz, at the head of Luribay waters, in the same department.

Bolivia was one of the countries that exported a large quantity of antimony ore during the war, for, whereas in 1914 the exports amounted to 183 long tons only, in 1915, 1916 and 1917 they reached 17,635, 26,255 and 22,994 long tons, respectively. The exported product was hand-sorted stibnite with a little antimony ochre and contained 50 to 55% antimony. In the middle of 1918 an embargo was placed on Bolivian ore in England, and exports fell off rapidly, only amounting to 6,712 long tons in that year. The chief producing areas during the war were in the Department of Potosí, especially Uncia, in the north, Porco, near the centre, and Atocha, in the south of the department. The veins proved to be small, but high in grade. They became barren at shallow depth [112/p. 47].

An analysis of high-grade ore from one of the principal mines yielded the following percentages: Antimony, 66; silica, 7·25; ferrous oxide, 1·32; lime, 2·6; sulphur, 14·04 [150].

At Tasna, 30 miles N.E. of Atocha, are important bismuth-bearing veins in slate cut by rhyolite dykes. In addition to the bismuth minerals, the veins contain pyrite, arsenopyrite, hæmatite and quartz, and, in smaller amounts, argentiferous galena, stibnite and siderite [149/p. 131].

Since the Great War the production of antimony ore in Bolivia has been insignificant.

Peru

Antimony is found in no less than eleven departments of Peru, but, with few exceptions, the mineral deposits are so situated that they cannot be worked at a profit except when the price of the metal is above the normal. The chief antimony-bearing departments, going from north to south, are the following:

Cajamarca.—In the San Felipe district, Province of Contumazá, quartz-stibnite veins containing pyrite and blende occur in metamorphosed sandstone. In the Province of Cajamarca, stibnite crystallized in needle-aggregates is found in limestone, which is separated by a dyke of trachyte from quartzite. In the Mina d'Antonio nodules of stibnite occur in a calcareous rock, assaying 20% antimony, and 3¼ oz. silver per metric ton. Attempts made in 1898 to exploit the deposit ended in failure.

Libertad.—In the Quiruvilca district, a vein with stibnite, 13 ft. in width, assays 28% antimony. In Cerro Negro, Province of Huamachuco, antimony lodes contain 50% antimony, and in Huaylillas, near-by, there are wide veins assaying from 30 to 35% antimony [151/p. 18].

In the Province of Santiago de Chuco argentiferous and ferriferous jamesonite occurs at Santa Rosa, crystallized in acicular aggregates. The country-rock is hornblende-andesite, and the gangue is quartz and gypsum. The ore is associated with tetrahedrite and pyrite. Crystallizations of both ore and gangue are common in the vugs (*laques*) [152].

Ancachs.—In the district of Recuay, Province of Huaraz, the Antimonia mine has stibnite crystallized in acicular form, and containing about 12½ oz. silver per ton. In the Cordillera of Uchutchacua, Province of Cajatambo, there are

quartz-stibnite lodes containing 38% antimony and about 5 oz. silver per ton. As a rule in this department the more antimonial the galena is, the richer is it in silver, but in the department of Cuzco the reverse seems to be the case.

Stibnite is found in the silver-bearing veins of the San Luis and Chacas district, Huari, together with the antimony minerals tetrahedrite, stephanite, polybasite and bournonite [153/p. 136].

Junín.—In the region of Huancavelica, Province of Cerro de Pasco, a quartz lode, from 1 to 10 ft. wide, contains stibnite, amorphous and in acicular form with bismuthinite and enargite. In the mineral region of Yauli are deposits of fibrous stibnite. Elsewhere in the department stibnite occurs crystallized in hornstone, in radial groups of crystals or in scaly compact masses.

Huánuco.—Some samples from this department assayed 68% antimony. At Ventanilla, stibnite is associated with gold.

Huancavelica.—Numerous antimony lodes are known in this department. The lode of La Caudalosa mine, Province of Castrovireyna, carries galena, blende, bournonite, pyrite, stibnite and tetrahedrite in stratified porphyries and porphyritic conglomerates. Beautiful crystals of stibnite occur on barytes near a vein, 18 in. thick, formed of quartz and crystallized stibnite, somewhat argentiferous. Small crystals of stibnite in pyrite accompanying tetrahedrite are regarded by the miners as a good indicator for gold [151].

Arequipa.—There are important deposits of stibnite in the mineral district of Caylloma.

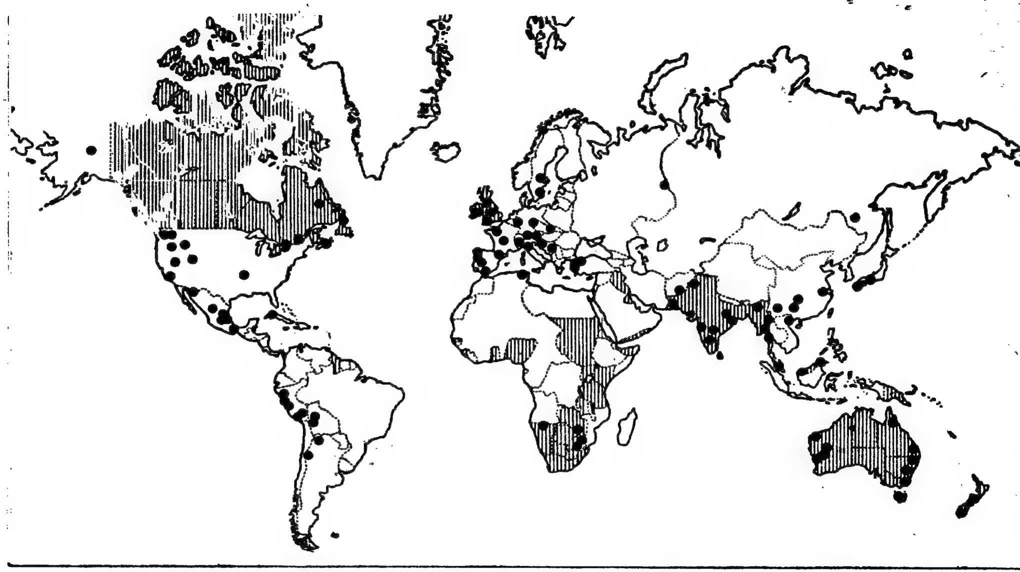
Cuzco.—In the mineral district of Chimboya (altitude, 15,000 ft.), Province of Canchis, are stibnite lodes carrying pyrite, galena and blende, in a gangue of quartz, calcite, and, occasionally, barytes. They have been described by Dueñas [154], who states that the greater the silicification of the lode the greater appears to be the proportion of antimony ore contained therein. The country-rock is highly altered porphyry, and the galena is usually rich in silver [153/p. 140].

Mining for antimony ore was begun in 1893 in the Province of Canchis, north of La Raya (Puno), and from Aguas Calientes,

near La Raya, about 600 tons of antimony ore, with 55 to 65% antimony, were exported to England from 1900 to 1906. The formation consists of sandstones (Tertiary), marls, limestones and porphyritic rocks [151/p. 24].

Puno.—Many veins of stibnite occur in the mining district of San Antonio de Esquilache. In the San José mine, the walls of the vein are formed of a marly clay, and the stibnite in the vein is crystallized and contains upwards of 70% antimony. In La Raya district, 5 miles to the north, there is a chain of hills formed of sandstone, limestone and quartzose conglomerate, in which a series of wide E.–W. veins contain stibnite, and assay up to 66% antimony. One of the veins is 16½ ft. wide. In the auriferous region of Santo Domingo, Province of Carabaya, stibnite and other antimony minerals are associated with pyrite and much native gold in a gangue of quartz. The country rock is a black ferruginous slate of Silurian age, which alternates with sandstones. The eruptive rock, which formed the fractures, is probably a porphyritic granite. According to C. I. Lissón [151/p. 26], the quantity of gold diminishes as the stibnite increases in amount, and increases in proportion to the remaining components, pyrite, tellurium, copper, quartz and slate. The order of deposition has been : Pyrite, gold, stibnite, quartz.

The first official figures of antimony production in Peru appeared in 1906, when ore was exported containing 91½ metric tons of antimony. In 1907 the exports amounted to 302 metric tons of antimony ore from Junín, Arequipa and Puno with 173, 69 and 60 metric tons respectively [151/p. 90]. From 1915 to 1918, the exports of ore amounted to 456, 1,589, 862, and 321 tons respectively [114/p. 8].



Map showing the Antimony-bearing Districts referred to in the Text. (British Empire shaded.)

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